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Wildlife Habitats of the North Coast of California: New Techniques for Extensive Forest Inventory

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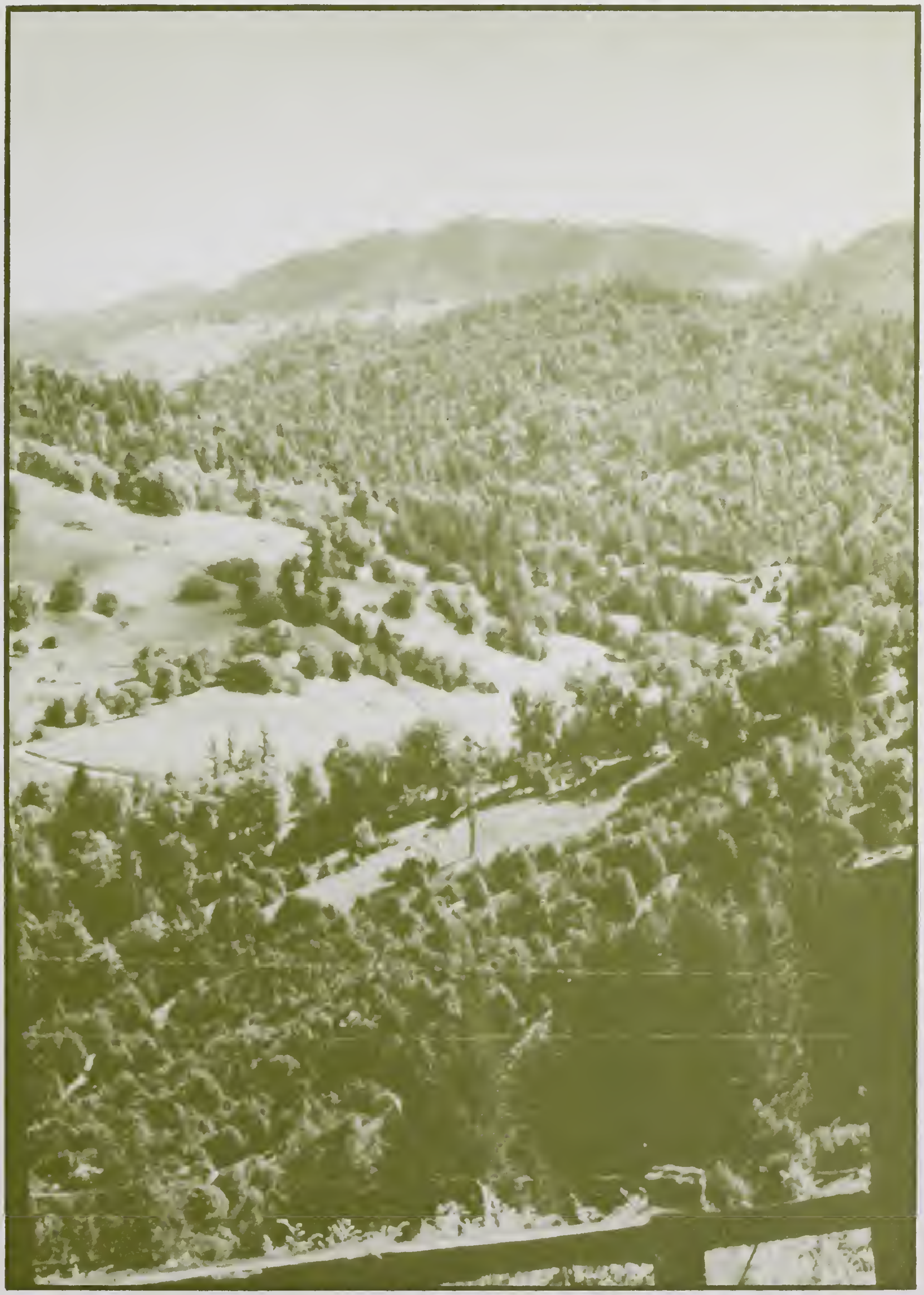

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Abstract

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A study was undertaken to develop methods for extensive inventory and analysis of wildlife habitats. The objective was to provide information about amounts and conditions of wildlife habitats from extensive, sample-based inventories so that wildlife can be better considered in forest planning and policy decisions at the regional scale. The new analytical approach involves identifying habitats present on field plots, estimating area present in each habitat condition, and linking the habitat classifications with wildlife-habitat relationship models to describe habitat suitability for wildlife species. The habitat classification system and wildlife-habitat relationship models of the California Wildlife Habitat Relationship Program are used in a case study of the north coast region of California. Tree vegetation types occupy 93 percent of all forest land, and shrub habitats occupy 5 percent. Redwood and Douglas-fir are the most abundant tree habitats; chamise-redshank chaparral is the predominant shrub habitat. Outside parks and National Forests, midsuccessional stages dominate the forest landscape in occupying two-thirds of the timberland area. Two-thirds of forest stands have moderate or dense canopy closure. The suitability of available habitats for reproduction and feeding for eight wildlife species are presented. The estimates of habitat area indicate the availability and patterns of occurrence of these vegetation conditions at a broad scale and should be useful in evaluating potential impacts of proposed actions affecting broad-scale alterations of habitat. The estimates of habitat suitability are used appropriately in regional-level predictions of species occurrence and habitat suitability. Extensive inventory data on special habitat elements such as snags, nontree vegetation, and spatial features of habitat also can be used in resource assessments and ecological research; for example, only 9 percent of the habitat area rated as being of high or medium suitability for reproduction for pileated woodpeckers supports snag habitat required by the species. Large snags are most abundant in dense, pole-sized and larger stands in the redwood type and in large-treed stands of all densities in the Douglas-fir type. Data from continuing forest inventories also are useful for regionallevel monitoring of wildlife habitats and in habitat simulations.

Keywords: Wildlife-habitat relationships, multiresource inventory, forest inventory, wildlife habitat assessment, snags, California (north coast).

Summary

As wildlife resources receive increasing attention in forest planning and management decisions at all levels, information on amounts, characteristics, and dynamics of habitat resources is needed. This paper presents new techniques of habitat inventory and assessment. The long-term goals of the study are to develop analytical approaches and products to facilitate multiresource planning and decisionmaking, and to develop the utility of extensive forest inventories for monitoring trends in wildlife habitats at stand, landscape, and regional scales. In the first phase of the study, presented in this paper, the habitat classification system and wildlife-habitat relationships models of the California Wildlife Habitat Relationships (WHR) Program are used in combination with data from the Forest Inventory and Analysis Work Unit (FIA) inventory in a case study of the north coast region of California. The FIA inventory provides data on

multiple resources from a grid of permanently established and periodically re-measured field plots. The analytical approach presented involves identifying habitats present on field plots, estimating area present in each habitat by using the two-phase design of the inventory, and linking habitat classifications with wildlife-habitat relationships models to describe habitat suitability for wildlife species.

Habitat characteristics along the north coast differ by geographic area and ownership. Redwood and Douglas-fir are the most extensive vegetation types in occupying 58 percent of all forest land. Data on habitat structure in parks and National Forests are unavailable. Midsuccessional stages dominate forest lands outside parks and National Forests, with pole and small-tree stands occupying two-thirds of the timberland. Two-thirds of forest stands have moderate or dense canopy closure. Structure of tree vegetation differs among and within the vegetation types. Valley foothill hardwoods generally occur in intermediate size classes and have the sparsest canopies. Conifer types—primarily redwood and Douglas-fir—growing on more productive sites tend to be the densest and grow to the largest size classes.

Chamise-redshank is the most abundant shrub type outside parks and National Forests. Structure of this habitat is quite homogeneous, with all area classified as mature and dense. The mixed chaparral type is more variable.

The level-one models of the WHR Program were used to translate habitat classifications of field plots into estimates of potentially suitable habitat for reproduction and feeding for eight wildlife species: Pacific giant salamander, California quail, northern spotted owl, pileated woodpecker, dusky flycatcher, fisher, mountain lion, and black-tailed deer. Outside parks and National Forests, about half the forest land has high or medium suitability for reproduction and feeding for black-tailed deer and mountain lion, which use shrubby, open stages of many vegetation types. About one-third of the area rates high or medium for reproduction and feeding for California quail and for spotted owl. Only 14 percent of the forest is of high or medium suitability for reproduction and feeding for pileated woodpecker. For fisher, 25 percent of the area is of high or medium suitability for reproduction and 40 percent for feeding. Sixty-four percent of the forest area provides high or medium feeding habitat for Pacific giant salamanders. Only 3 percent of the area has high or medium suitability for reproduction and feeding for dusky flycatchers, which prefer higher elevation forest. Potentially suitable habitat for these species in parks and National Forests is probably quite different.

The estimates of habitat area indicate general availability of these vegetation conditions at a broad scale along the north coast. The data can be used to assess potential impacts of proposed actions affecting broad-scale alterations of habitat. The habitat-suitability ratings are best interpreted as relative probabilities of occurrence of a species in different habitats; area estimates of suitable habitat are appropriately used in regional-level predictions of species occurrence and habitat suitability. Many factors not accounted for in the level-one models affect actual animal occurrence and abundance, including special habitat elements, the areal extent and spatial arrangement of habitat, and human activity. Adjusting for the effects of these factors would reduce the estimated area of suitable habitat. Density of snags suitable for pileated woodpecker nesting, for example, meets the required 15 per 40 hectares in stands rated as high suitability for reproduction, but not in stands rated as medium or low. Large snags are most abundant in dense, pole-sized and larger stands in the redwood type and in large-treed stands of all densities in the Douglas-fir type.

Inventory data reveal no consistent relations between tree canopy closure and shrub canopy closure among the WHR habitats. I recommend direct field observation of snag populations and shrub understories in a management context.

The spatial arrangement of habitats, an important consideration for wildlife, is neither accounted for in the level-one models nor easily addressed at regional scales by using extensive, sample-based inventories. Current technology does allow for the display of generalized patterns of occurrence of wildlife habitats through the plotting of sample locations on a base map, and several such maps are presented. Spatial features of habitat at a finer level of resolution than these plotted maps could be assessed by integrating new measurements with the existing sample framework, or by applying recent technology in remote sensing and geographic information systems.

Data from continuing, extensive forest inventories provide a unique opportunity to evaluate possible future scenarios for trade-offs among resource benefits through use of habitat simulation and forest projection models. Furthermore, repeat measurement of permanent plots will provide information for long-term monitoring of changes in biological diversity at the forest stand, landscape, and regional levels.

Contents

Background

Forest Habitat Inventories and Assessments Needed

Wildlife resources are gaining recognition in forest decisionmaking at all levels, from local forest management to national resource policymaking. Federal, State, and local laws demonstrate the public's expectation that wildlife will be considered along with other forest resources in management and planning decisions. This task is now more complex than ever before, as emphasis has expanded beyond populations of game species to include the full array of wildlife and their habitats. Attention increasingly focuses on the broader goal of conserving biological diversity at many scales including forest community, landscape, and region.

Survival of wildlife populations depends mainly on the amount of suitable habitat. Planners and managers need basic information about current and possible future amounts and conditions of wildlife habitats before they can adequately consider wildlife in their decisions. Techniques for developing this kind of information currently are limited, however. In this paper, I present various approaches to evaluating habitat resources by using extensive forest inventories. I focus on the recent Forest Inventory and Analysis (FIA) inventory of California—and the north coast (fig. 1) in particular—as a case study.

Wildlife Issues of the North Coast of California

The north coast region of California—including Del Norte, Humboldt, Mendocino, and Sonoma Counties—contains 6 percent of the land area and 22 percent of the timberland in California (see "Terminology" for definitions of terms used) (fig. 1). Over three-fourths (78 percent) of the region is forested (table 1). Increasing and competing demands on these forests for goods and services have sparked several wildlife-related issues; for example, the public demands continued availability of populations of harvest species of wildlife. At the same time, concern grows over the conversion of extensive, unmanaged stands of mature and old-growth forest to young, even-aged stands characterized by fewer tree species and reduced structural diversity. Data from the recent FIA inventory indicate that only 1 percent of timberland stands outside parks and National Forests are over 200 years old (fig. 2). Remaining stands of old growth are becoming smaller and more isolated (Rosenberg and Raphael 1986). The resulting forest landscape, a patchwork of stands of contrasting ages and management histories, may provide improved habitat for some species of wildlife but fewer resources for others. Of particular concern are wildlife species requiring large contiguous blocks of mature or old-growth forest.

A related concern is the effect of intensive forest management on amounts and characteristics of coarse woody debris and the role of this material as habitat for wildlife. Managed forests have fewer snags and fallen trees than unmanaged stands (Cline and others 1980). Forests with fewer large snags provide less habitat diversity and may be incapable of supporting viable breeding populations of some native species of wildlife.

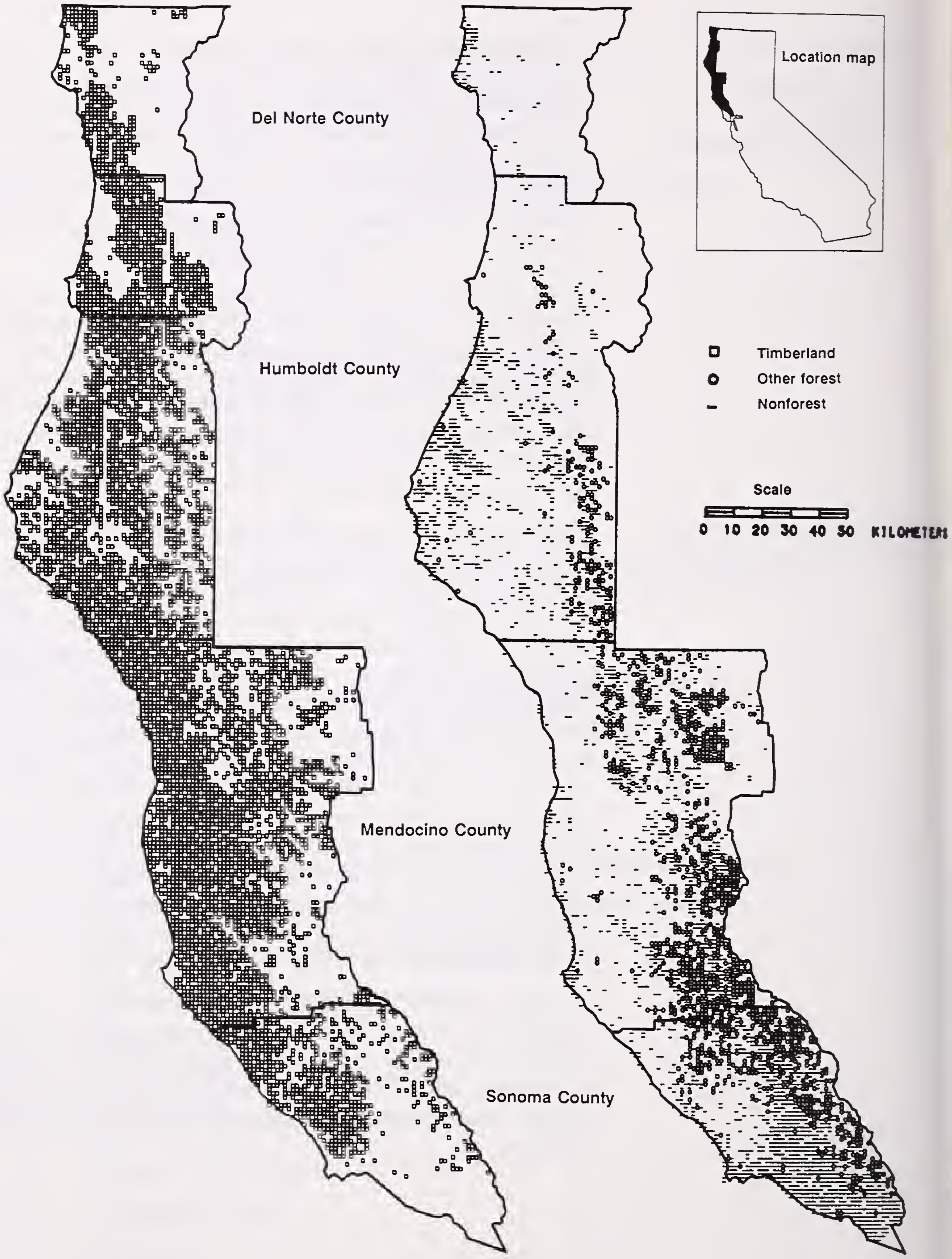
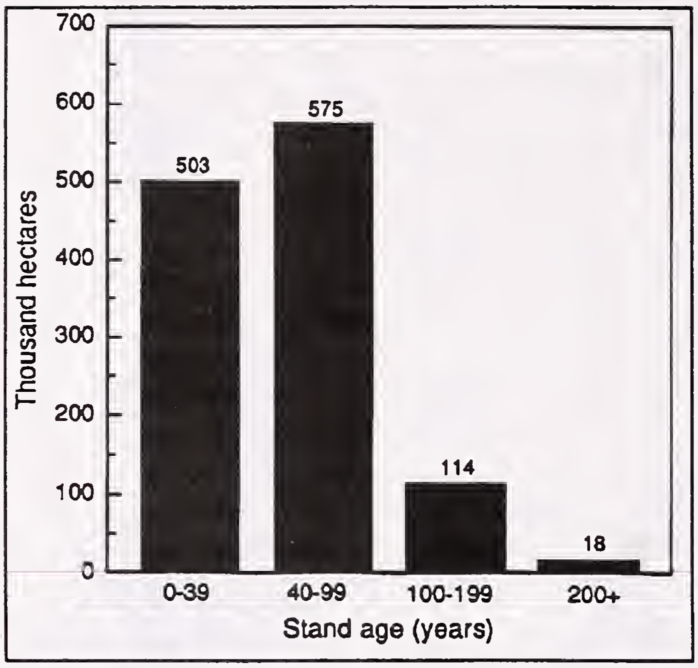


Figure 1—General patterns of major land classes on lands outside parks and National Forests along the north coast of California, 1985. Each symbol represents the classification of a 0.4-hectare area based on aerial photo interpretation. Each symbol represents about 192 hectares.

Table 1--Area by county, ownership class, and land class, north coast, California, January 1, 1985[a b c]

County and ownership class	Timberland			Other forest			Total forest	Nonforest	Total area
	Unreserved	Reserved	Total	Unreserved	Reserved	Total			
				Thousand hectares					
Del Norte County:									
National Forest	93	18	111	49	8	56	168	5	173
Outside National Forest	68 ± 2	10	78	--	d	d	79	14 ± 2	93
All owners	161	28	189	49	8	57	246	19	265
Humboldt County:									
National Forest	110	4	114	15	2	18	132	4	136
Outside National Forest	524 ± 11	42	566	45 ± 9	3	47	613	164 ± 10	777
All owners	635	45	680	60	5	65	745	168	913
Mendocino County:									
National Forest	46	1	47	18	1	19	66	5	71
Outside National Forest	495 ± 19	4	499	167 ± 17	d	167	666	177 ± 11	843
All owners	541	5	546	185	1	186	732	182	914
Sonoma County:									
National Forest	--	--	--	--	--	--	--	--	--
Outside National Forest	112 ± 8	1	113	90 ± 9	6	96	209	187 ± 9	395
All owners	112	1	113	90	6	96	209	187	395
All counties:									
National Forest	251	22	272	82	11	93	365	15	380
Outside National Forest	1,210 ± 22	57	1,267	304 ± 21	10	313	1,580	539 ± 16	2,120
All owners	1,461	79	1,539	385	21	406	1,945	554	2,499

-- = none found.
[a]Totals may be inexact because of rounding.
[b]Specific data for National Forest lands dedicated as wilderness in the 1984 California Wilderness Bill were not available. In most cases, the 1984 wilderness additions represent a portion of the area reported as "reserved."
[c]Confidence intervals are for the 68-percent probability level.
[d]Less than 500 hectares.



Figure—2 Timberland outside parks and National Forsts by stand age, north coast, California, 1985

The habitat value of hardwoods has long been appreciated, and interest is growing (Bolsinger 1988, Plumb and Pillsbury 1987). Many fear that habitat provided by oak woodlands in the State is being lost to nonforest land uses. On timberlands along the north coast, hardwood types such as tanoak (*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.) have increased significantly—by about 287,000 hectares—over the past 40 years (Bolsinger 1988). The situation generally is attributed to selective logging of conifers between the early 1950s and 1975. Raphael (1987b) found evidence that tanoak is an important habitat component for at least 16 of 61 sampled vertebrate species in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) forests of northwestern California. Pacific madrone (*Arbutus menziesii* Pursh) is an important component of cavity-nesting bird habitat in these same forests (Raphael 1987a). The effects on wildlife of past and future changes in species composition of the forests of the region are unclear.

Whereas much of the current controversy over resource allocation focuses on public lands, all forest lands should be considered in planning and decisionmaking. Issues of biological diversity do not stop at ownership and political boundaries. New and innovative uses of data from extensive, multiresource forest inventories can help define and focus regional-level concerns about wildlife and other forest resources as well as provide insight on causes, trends, and possible solutions. Analyses also may identify new problems, opportunities, and areas for further study.

Habitat Inventories by FIA: A Long History

Although the need for extensive habitat inventories long has been recognized (Moore and others 1960), little information on the extent, distribution, and condition of wildlife habitat has been available in the United States. Virtually all efforts to produce such information about non-Federal lands have been conducted by the various FIA research units or their cooperators. The FIA is a nationwide project of the USDA Forest Service. Past assessments of wildlife habitat by FIA range from evaluations of single species to broad multispecies efforts (Barnes and Barnard 1979, Lennartz and McClure 1979, Sheffield 1981). Most of these evaluations are "snapshots" in time of

available habitat for one or a few selected wildlife species. Other recent efforts describe the condition of one or more habitat elements, such as snags, browse, or edge (Brooks 1986; Brooks and Scott 1983; Brooks and others 1987; LaBau and others 1986; McComb and others 1986a, 1986b). Analyses of past trends in habitat conditions have necessarily relied heavily on historical information from timber resource inventories (Brooks 1989, Ohmann 1989). Habitat assessments at the national level, such as the periodic Resources Planning Act (RPA) assessments conducted by the USDA Forest Service, also have been constrained by lack of data specifically related to habitats. Broad-scale projections of future habitat conditions are even less available.

New Inventory Techniques Needed for Pacific Coast States

Methods of habitat assessment applied to inventories in other parts of the country are not directly applicable to the particular inventory design, ecological conditions, wildlife species, analytical models, and current resource issues and concerns of the Pacific Coast States. Planning-level information about wildlife habitats on forest lands is currently quite limited—particularly for non-Federal lands. The FIA inventory offers several advantages as a source of such information. The sample design provides consistent data across large geographic areas and many ownerships. The sample grid of photo and ground plots is permanently established and periodically remeasured, thereby offering an opportunity for habitat monitoring. Most importantly, the FIA inventory provides multiresource data from the same sample points. The concept of assessing wildlife habitat by using data from an extensive, sample-based inventory is relatively new, however. Before such an assessment could be undertaken, an approach to collecting, analyzing, and presenting appropriate information was needed.

In response to new information needs and broadened legislative direction, FIA began expanding field data collection in the mid-1970s to include features of vegetation important for evaluating wildlife habitat. It was correctly assumed that much of the data traditionally collected for assessing timber resources would be useful in describing habitat resources. During the 1980s these procedures were modified and improved based on field experience and evolving information needs. Yet until recently, no analyses of the habitat data had been undertaken, and analytical models for applying the habitat data were lacking. Planning for the FIA inventory of California in the late 1970s coincided with development of new wildlife-habitat relationships models for the State (Grenfell and others 1982, Verner and Boss 1980), which included a system for classifying vegetation.[1]

Study Objectives

The events discussed above formed the impetus for a study to develop techniques to evaluate wildlife habitat by using data from an extensive, sample-based inventory (Ohmann 1983, 1990; Ohmann and Mayer 1987). This paper describes the first phase of the study, and focuses on the California north coast as a case study. In this paper, I (1) present inventory techniques for producing information on current habitat conditions, including methods and problems of linking extensive inventory

[1] Salwasser, Hal; Laudenslayer, William F., Jr. 1982. California Wildlife and Fish Habitat Relationships (WFHR) System: products and standards for wildlife. Appendix 3. Unpublished document. On file with: USDA Forest Service, Pacific Southwest Region, 630 Sansome Street, San Francisco, CA 94111.

data with wildlife-habitat relationships models; and (2) demonstrate examples of applications of the habitat data base in evaluating habitat suitability for wildlife species. The long-range goals of the study are (1) to improve multiresource decisionmaking by allowing evaluations of tradeoffs between production of timber and wildlife resources, and (2) to develop the utility of extensive inventories for monitoring trends in biological diversity at a regional scale.

An Analytical Approach

Several features within an approach to extensive habitat inventory and evaluation are desirable. Procedures ideally should mesh with any existing sample design and time frame to minimize costs, maintain continuity of an established inventory, and facilitate multiresource analyses. The inventory and analysis should provide habitat information for many customers with different interests and degrees of technical expertise. The inventory data base also should be versatile enough to address several resource issues that may arise over a relatively long time—at minimum the inventory remeasurement cycle. Of the many approaches to habitat assessment that have evolved over recent years, none best meets all possible goals (Thomas 1982). For this phase of the study I applied models developed by the California Wildlife Habitat Relationships (WHR) Program (Grenfell and others 1982), which are patterned after Patton (1978) and Thomas (1979). This approach is flexible for meeting current and future information needs. The WHR models have been developed for the full array of California wildlife and follow a standard format. The WHR Program was developed by the National Forest System and is supported by the California Interagency Wildlife Task Group. Information can be presented in terms meaningful to a large and diverse user group.

The analytical approach to an extensive, sample-based inventory of wildlife habitats (fig. 3) involves first identifying the habitat present on individual field plots, through the WHR system for habitat classification (Mayer and Laudenslayer 1988). By using the basis for sample area stratification developed in the inventory, the area in each of the WHR habitats can be estimated for a defined geographic region. In addition, the habitat classifications of field plots can be linked with the WHR species-habitat relationships models to describe how well current forest conditions meet the life requisites of wildlife species. These steps are described in detail later in this paper.

Lands Covered

Techniques presented in this paper apply primarily to lands sampled in the FIA inventory: all forest lands except reserved areas (primarily National, State, and county parks) and National Forests. I focus on these lands, which represent 78 percent of all forest land along the north coast (table 1), because inventory data suitable for applying the new procedures are unavailable for parks and National Forests. To provide an overall picture of vegetation types present on all ownerships and land classifications in the region, I translated estimates of area by forest type as reported by Lloyd and others (1986: table 6A) into area estimates of corresponding WHR vegetation types. Forest type data for reserved areas were obtained in telephone interviews with local park officials. For National Forest lands, data on forest type were collected by National Forest personnel using a mapping technique.[2] In this paper, tables and figures showing area by vegetation type represent forest land of all ownerships. Data on vegetation structure needed for identifying the size, age, and canopy closure

[2] For more information contact: USDA Forest Service, Pacific Southwest Region, 630 Sansome Street, San Francisco, CA 94111, or Pacific Northwest Region, P.O. Box 3623, Portland, OR 97208-3623.

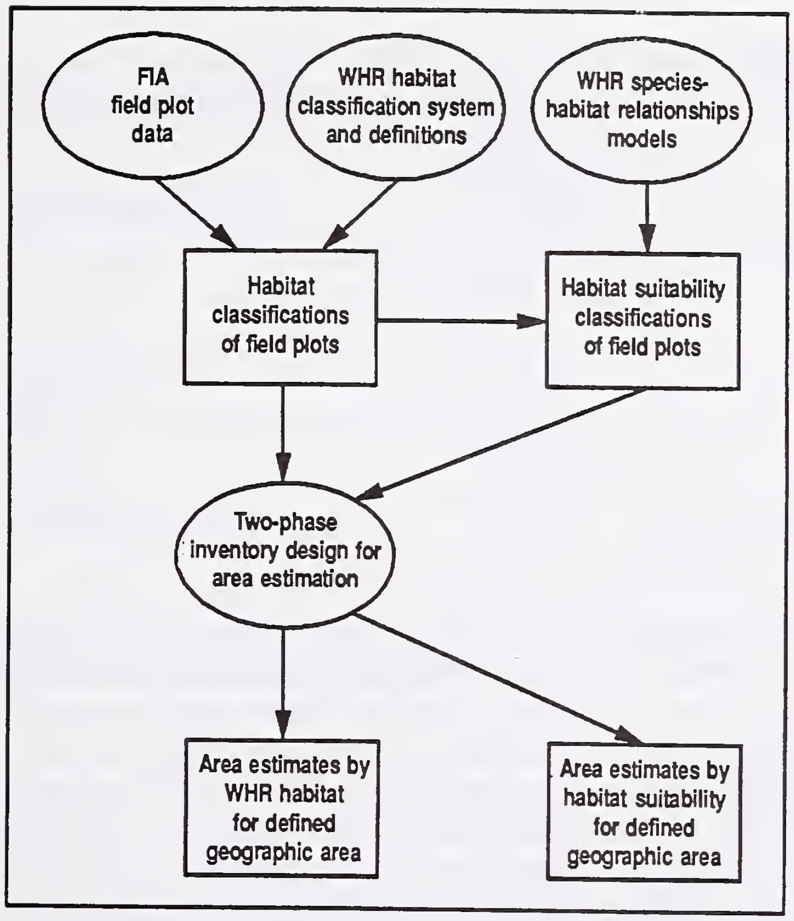


Figure 3—Analytical approach to extensive inventory of wildlife habitats using FIA inventory data and WHR models.

classes of forest habitats are unavailable for parks and National Forests. Tables and figures on habitat structure and habitat suitability therefore pertain only to forest lands outside parks and National Forests.

The FIA Inventory Design and Data

Detailed descriptions of the FIA inventory procedures are found in McKay (1987) and in the California field manual.[3] Lands outside parks and National Forests were inventoried by FIA with a design approximating Cochran's (1977) double sampling for stratification. A primary sample of 10,823 aerial photo points, with an average grid interval of 1.37 kilometers, was mapped and referenced by Universal Transverse Mercator (UTM) coordinates (Thompson 1979). Each photo point was classified by broad ownership class, land class, timber volume class, and canopy cover class. A total of 656 field plots were located at every 16th photo point, about 5.5 kilometers apart. At each of 380 ground locations on timberland, field crews established or remeasured a permanent inventory plot. The 97 ground locations on other forest land were field-checked for land classification, and field plots were installed at a one-quarter subsample of the ground locations (19 plots). Field plots consist of five sample points over 2 hectares. At each sample point, live trees were tallied on a series of fixed- and variable-radius plots. Species, height, diameter at breast height (d.b.h.), vigor, stand position, age, and presence of damaging agents were recorded for each tree. Snags

[3] U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Renewable Resources Evaluation Work Unit. 1981. Resources Evaluation field instructions for California, 1981-1984. On file with: Pacific Northwest Research Station, P.O. Box 3890, Portland, OR, 97208-3890.

(standing dead trees) at least 22.5 centimeters d.b.h. and 2 meters tall also were tallied, and their species, d.b.h., height, decay class, and presence of cavities or dens were recorded. The structure and species composition of vegetation were recorded on 5-meter fixed-radius plots centered on each of the five sample points. At sample-locations in chaparral, vegetation was sampled on one 17-meter fixed-radius plot. The height and percentage of foliar cover of each species were estimated visually. Shrub species were characterized by stage of development as defined by the amount of dead material in the crown. The mean percentage of cover of individual species and canopy layers on the plot was calculated by averaging the cover estimates of the five sample points. Characteristics of the general plot area also were recorded, including precipitation, elevation, slope, aspect, CALVEG series,[4] stand origin, most recent activity, soil depth, and impact of fire, insects, disease, animals, and nontimber uses. Field plots along the north coast most recently were measured from 1981 to 1984 and will be remeasured every 10 years.

Classifying Habitats Presents on FIA Field Plots

Before habitat area could be estimated, field plots had to be categorized by the WHR habitat present. The WHR habitats broadly define the different kinds of environments occupied by wildlife in California. They are characterized by the existing, dominant vegetation (vegetation type, or "habitat") and by its structural conditions (habitat "stage"). Vegetation structure is defined by (1) the average size class of dominant trees (for tree vegetation types) or the average age class of dominant shrubs (for shrub vegetation types), and (2) the canopy closure by the dominant plants. Where possible, habitat classifications were based on quantitative rules applied to field measurements, rather than on subjective field observations, to ensure objective and consistent classifications and to facilitate objective assessments of habitat change following remeasurement of the permanent plots.

Vegetation Types

The WHR vegetation types present on field plots were identified by translating field-recorded CALVEG series and using guidelines provided by Salwasser and Laudenslayer (see footnote 1) and de Becker and Sweet (1988). In the field, CALVEG series were identified by canopy closure and life form of the dominant, existing vegetation. If the tree layer comprised at least 25-percent cover, the CALVEG series was assigned by the dominant tree species. If tree cover was less than 25 percent, CALVEG series was identified by the dominant species in the shrub layer. If neither the tree nor the shrub layer comprised 25-percent cover, the herbaceous layer was classified. In the office, CALVEG series were translated into corresponding WHR vegetation types as indicated in the appendix. In cases where the CALVEG series alone was insufficient for classifying WHR vegetation type, additional data on geographic location and on the species composition and structure of the vegetation were used. Under the CALVEG system, for example, tree series have at least 25-percent cover of existing trees, whereas the WHR tree types are based on the potential of a site to support at least 10-percent tree cover. Plots with less than 25-percent tree cover therefore were assigned shrub or herbaceous CALVEG series in the field and had to be reassigned a tree WHR type. Plots supporting less than 10-percent tree cover as a result of disturbance were assigned a tree vegetation type based on the vegetation that potentially would develop on the site.

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[4] U.S. Department of Agriculture, Forest Service. 1981. CALVEG—a classification of California vegetation. Unpublished document. On file with: Regional Ecology Group, USDA Forest Service, Pacific Southwest Region, 630 Sansome Street, San Francisco, CA 94111. 168 p.

Size and Age Classes

Stands of trees with a single canopy layer were assigned one of the following size classes based on the quadratic mean diameter of overstory trees:

Tree size class	Quadratic mean diameter
	Centimeters
Seedling	<3
Sapling	3-15
Pole	15-28
Small	28-61
Medium to large	>61

Trees much younger and smaller than those in the main canopy layer (such as seedlings growing under large trees) were not included in the calculation of quadratic mean diameter. Scattered residual overstory trees, usually trees left after timber harvesting, also were excluded. In hardwood vegetation types, only hardwoods were included in the calculation of quadratic mean diameter; in conifer types, only conifer trees were used. Plots on forest land currently supporting less than 10-percent tree cover as a result of disturbance were classified as seedling stands.

Plots in redwood, Douglas-fir, Klamath mixed conifer, and montane hardwood-conifer vegetation types were screened to determine if they qualified as multilayered. Multilayered stands have at least 20-percent canopy closure of trees in the medium to large size class (>61 centimeters d.b.h.), at least 20-percent canopy closure of trees in the pole and small-tree size classes (15-61 centimeters d.b.h.), and total canopy closure of 60 percent or more. To determine the canopy closure of trees by size class, the range of tree heights associated with each size class was first identified from height data from the tree list for the plot. With the data recorded on the vegetation profile for the plot, the values for percentage of canopy closure of trees within each height range were summed. I assumed that canopy overlap among trees of a given size class is minimal and that this approach therefore does not overestimate canopy closure of a particular size class.

Field plots assigned shrub vegetation types were categorized by the following age classes based on the amount of dead material present in the crowns. The seedling and young age classes were grouped for this analysis:

Shrub age class	Dead material in crowns
	Percent
Seedling and young	0
Mature	1-25
Decadent	25

Canopy Closure Classes

Tree and shrub plots were classified by percentage of canopy closure. The WHR classes indicate the percentage of the ground obscured by a vertical projection of all tree crowns (in tree vegetation types) or shrub crowns (in shrub vegetation types), as would be interpreted from aerial photographs:

Canopy closure class	Canopy closure
	Percent
Sparse	0-24
Open	25-39
Moderate	40-59
Dense	60-100

On field plots, canopy closure was estimated for each combination of plant species and height class. Because of crown overlap of trees, a sum of individual cover values overestimates canopy closure as defined in the WHR model. To exclude overtopped, understory trees, only those trees at least 25 percent as tall as the tallest canopy layer were included in the estimate of canopy closure. An informal study I did showed this "adjusted" canopy closure approximates crown cover as interpreted from aerial photographs.

Estimating Current Habitat Area and Associated Sampling Error

Procedures

After the field plots were classified by the habitat present, the area of each habitat along the north coast was estimated with the two-phase design. In this procedure, total area sampled in the four counties was determined by subtracting the area in parks, National Forests, and large bodies of water from the total area reported by the U.S. Bureau of the Census. An area expansion factor for the photo interpretation points was calculated by dividing total sampled area by the total number of photo points. Area by stratum, with stratum defined by owner class, land class, and timber volume class, was determined by summing the number of photo points in each stratum and multiplying by the area expansion factor.

The standard double-sampling procedure (Cochran 1977: 327-335) was used with field plot classifications of land class and volume class (for timberland) to adjust the estimates of area in each stratum and to calculate associated standard errors. Owner classification was assumed to be without error. Additional sampling error was incurred in estimating the proportion of each stratum falling in each habitat classification. Because timberland and other forest strata were field-sampled at different intensities, standard errors for habitats occurring in both land classes were calculated separately for the two land classes and then combined by using a weighted average. (Eighty percent of the forest land along the north coast is timberland and 20 percent is other forest.) Standard errors are presented for representative estimates of habitat area for lands sampled by FIA. Data for National Forests are determined with a mapping technique and hence have no sampling error.

Along the north coast, 13,000 hectares of other forest land classified as rocky or wetland sites by the two-phase sample were not subsampled by field plots. This area is identified as "unclassified" in tables 2 and 3 and is included in neither the remaining tables and figures nor the discussion in the text.

Table 2--Area of forest land in all ownerships by WHR vegetation type and land class, north coast, California, January 1, 1985[a]

Vegetation type	Timberland	Other forest	Total forest
	Thousand hectares		
Tree types:			
Redwood	601	--	601
Douglas-fir	508	26	534
Klamath mixed conifer	77	8	85
White fir	5	--	5
Red fir	1	b	1
Subalpine conifer	1	--	1
Ponderosa pine	15	1	16
Closed-cone pine-cypress	3	8	11
Montane hardwood-conifer	62	--	62
Montane hardwood	251	136	386
Montane riparian	b	1	1
Valley-foothill riparian	3	--	3
Valley-foothill hardwoods--			
Coastal oak woodland	6	51	57
Blue oak woodland/ blue oak-Digger pine	4	1	4
Valley oak woodland	3	34	37
Unclassified oaks	--	4	4
Subtotal, valley-foothill hardwoods:	13	89	102
Total, tree types	1,539	269	1,808
Shrub types:			
Chamise redshank	--	51	51
Mixed chaparral	--	38	38
Montane chaparral	--	12	12
Unclassified chaparral	--	5	5
Total, shrub types	--	106	106
Nonstocked forest land	1	19	20
Unclassified	--	13	13
All forest land	1,541	407	1,947

-- = none found.
[a]Totals may be inexact because of rounding.
[b]Less than 500 hectares.

Table 3--Area of forest land by WHR vegetation type, reserved status, and ownership class, north coast, California, January 1, 1985[a, b]

Vegetation type	Unreserved: National Forest	Unreserved: Other public	Unreserved: Private	Unreserved: Total	Reserved: National Forest	Reserved: National parks	Reserved: State parks	Reserved: County and municipal	Reserved: Private	Reserved: Total	Total forest
					Thousand hectares						
Tree types:											
Redwood	1	30	522	552	c	25	25	c	--	50	602
Douglas-fir	189	43	282	514	17	c	2	c	1	20	534
Klamath mixed conifer	73	--	3	76	9	--	--	--	--	9	85
White fir	5	--	--	5	c	--	--	--	--	c	5
Red fir	1	--	--	1	--	--	--	--	--	--	1
Subalpine conifer	c	--	--	c	c	--	--	--	--	c	1
Ponderosa pine	5	3	8	15	--	--	--	--	--	--	15
Closed-cone pine-cypress	7	--	3	10	c	--	1	--	--	1	11
Montane hardwood-conifer	--	10	53	62	--	--	--	--	--	--	62
Montane hardwood	21	38	321	380	2	--	5	--	--	7	386
Montane riparian	c	--	--	c	c	--	c	--	--	1	1
Valley-foothill riparian	--	--	3	3	--	--	--	--	--	--	3
Valley-foothill hardwoods:											
Coastal oak woodland	c	--	57	57	c	--	--	--	--	c	57
Blue oak woodland--blue oak digger-pine	1	--	4	4	c	--	--	--	--	c	4
Valley oak woodland	--	17	20	37	--	--	--	--	--	--	37
Unclassified oak types	--	--	--	--	--	c	3	c	c	4	4
Total	1	17	81	98	c	c	3	c	c	4	102
Total, tree types	302	140	1,274	1,717	28	25	36	c	1	91	1,808
Shrub types:											
Chamise-redshank	2	13	37	51	c	--	--	--	--	c	51
Mixed chaparral	1	13	25	38	c	--	--	--	--	c	38
Montane chaparral	11	--	--	11	1	--	--	--	--	1	12
Unclassified chaparral	--	--	--	--	--	3	2	c	c	5	5
Total, shrub types	13	25	62	100	1	3	2	c	c	6	106
Nonstocked	17	--	--	17	3	--	--	--	--	3	20
Unclassified	--	3	10	13	--	--	--	--	--	--	13
All forest land	332	165	1,336	1,833	33	28	37	1	2	101	1,934

-- = none found.

[a] Totals may be inexact because of rounding.

[b] Specific data for National Forest lands dedicated as wilderness in the 1984 California Wilderness Bill were not available. In most cases, the 1984 wilderness additions represent a portion of the area reported as "National Forest--Reserved."

[c] Less than 500 hectares.

Results

The vegetation structure and composition, biological and physiographical setting, and distribution of the habitats are described in Mayer and Laudenslayer (1988). Redwood and Douglas-fir are by far the most extensive vegetation types along the north coast, occupying 58 percent of the forest land (tables 2 and 3). The redwood type prevails because mixed stands of redwood (*Sequoia sempervirens* (D. Don) Endl.) and Douglas-fir were classified as redwood. Forests dominated by Sitka spruce (*Picea sitchensis* (Bong.) Carr.), grand fir (*Abies grandis* (Dougl. ex. D. Don) Lindl.), or red alder (*Alnus rubra* Bong.) also were included in the redwood type. Chamise-redshank is the most abundant WHR shrub type; along the north coast this type consists entirely of chamise (*Adenostoma fasciculatum* H. & A.). Vegetation types differ by geographic location (fig. 4) and by owner class (table 3). National Forest lands along the north coast are generally higher in elevation and farther inland than private ownerships and encompass a different mix of vegetation types, stages, and presumably, wildlife species. Nearly all the mixed conifer, white fir, red fir, subalpine conifer, and montane chaparral vegetation types occur on the National Forests, as does 38 percent of the Douglas-fir type. But National Forests also contain less than 1 percent of the north coast redwood and valley-foothill hardwood habitats and only 3 to 4 percent of the chamise-redshank chaparral and mixed chaparral vegetation types.

Midsuccessional stages dominate the forest landscape: pole and small-tree stands (15-61 centimeters d.b.h.) occupy two-thirds of the timberland outside parks and National Forests (figs. 5 and 6). Moderate to dense canopy closure predominates, with 66 percent of the tree habitats occurring in this condition (table 4). Size and canopy closure differ greatly among and within the vegetation types, however. The valley foothill hardwoods occur exclusively in the intermediate size classes (pole and small tree). Except for coastal oak woodland, which tends to be dense, the valley-foothill hardwoods generally occur in a sparse, savannalike condition. The montane hardwood-conifer and montane hardwood types encompass several plant communities as a function of both site conditions and disturbance history; hence, they are quite variable in structure. Conifer types growing on more favorable sites tend to have dense canopies—about half of the redwood and Douglas-fir area is of dense canopy closure. Redwood and Douglas-fir are the only two types currently reaching the large-tree and multilayered size classes on lands sampled by FIA.

None of the sampled shrub vegetation types was classified in the seedling or young age classes or as having sparse canopy closure (table 5). Habitat structure of the chamise-redshank type is quite homogeneous, with all sampled area classified as mature and dense. Mixed chaparral is more variable.

Text Continues on page 19

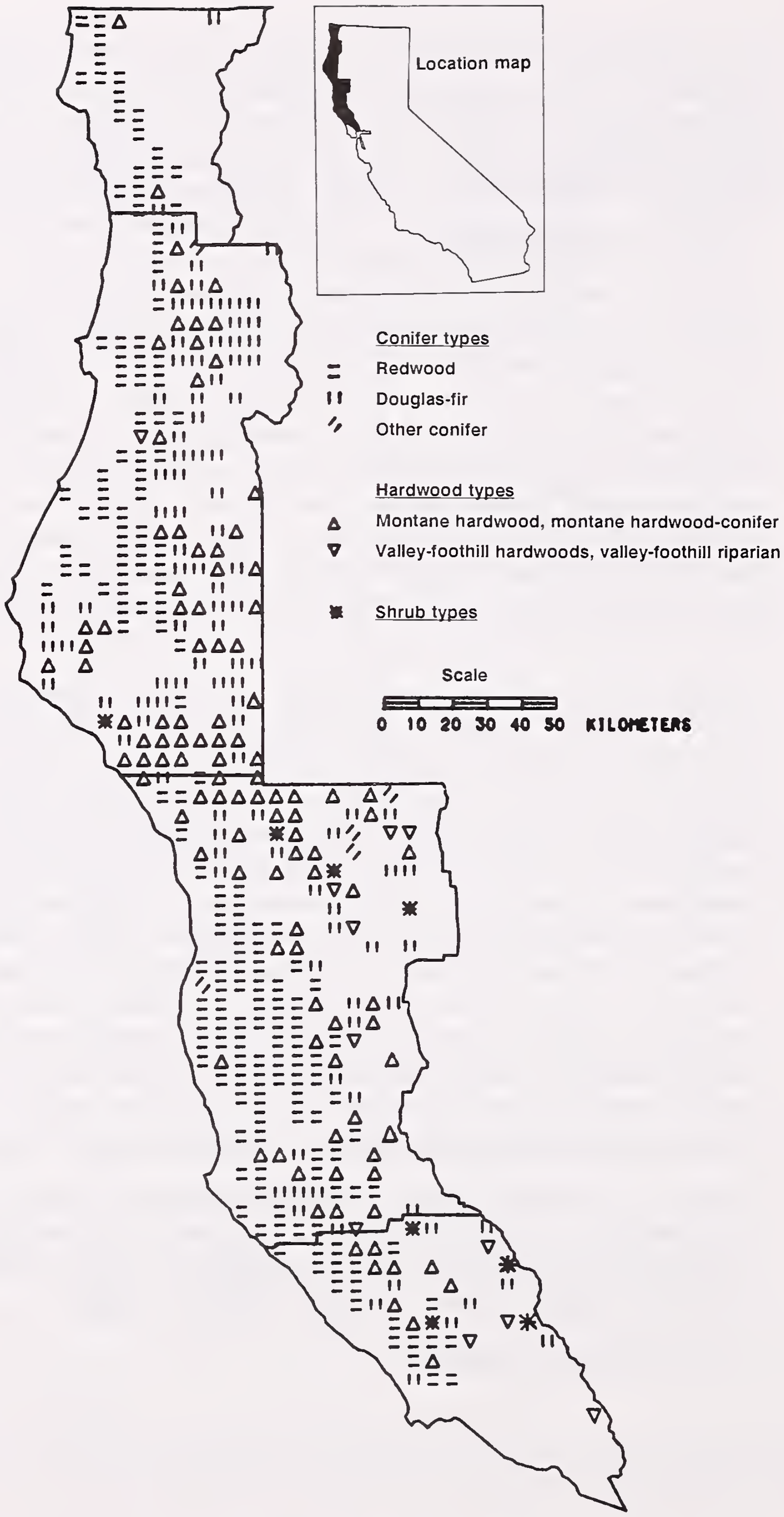

Figure 4—WHR vegetation types sampled on field plots on forest land outside parks and National Forests, north coast, California, 1985. Each symbol represents an average of 3,185 hectares (timberland plots) or 15,307 hectares (other forest plots).

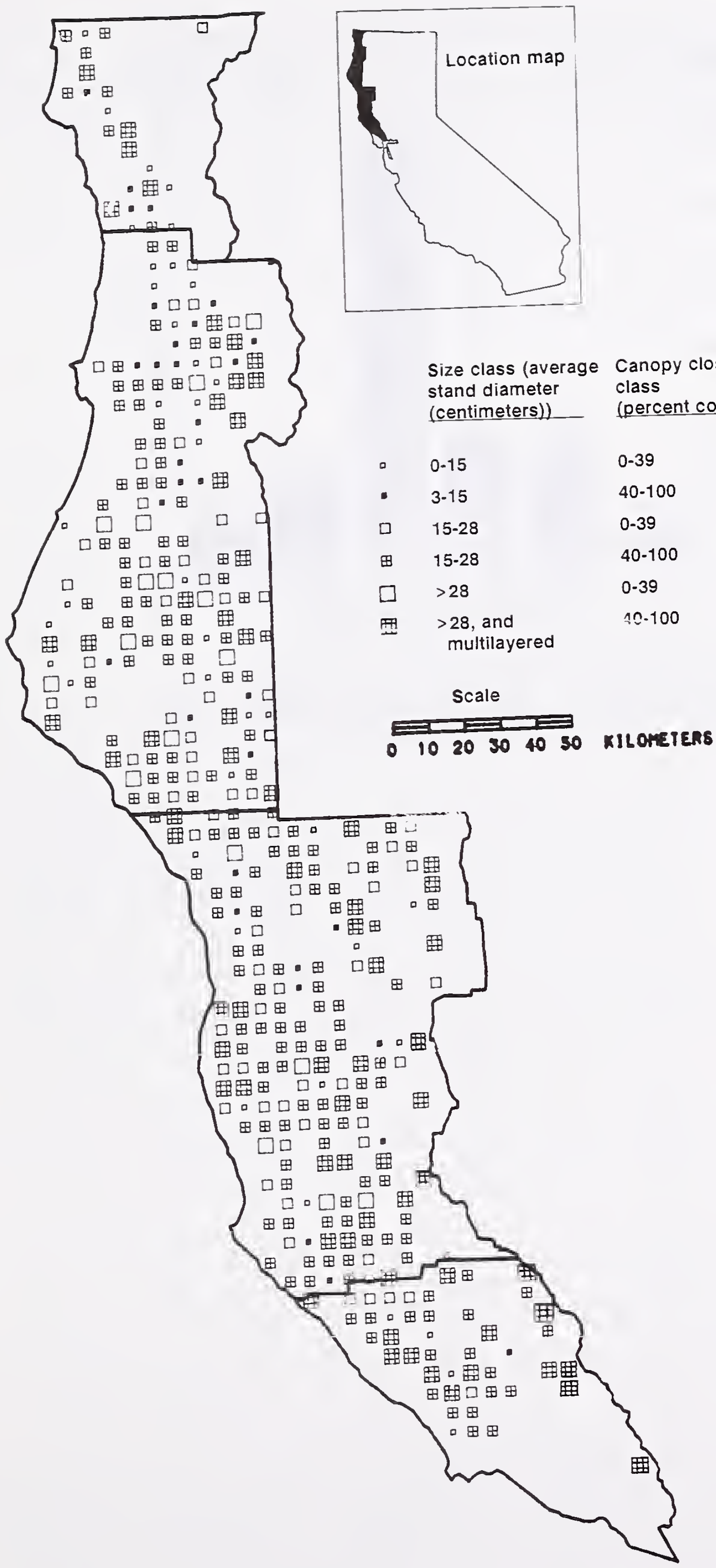

Figure 5—WHR size and canopy closure classes on field plots on timberland outside parks and National Forests, north coast, California, 1985. Each symbol represents an average of 3,185 acres.

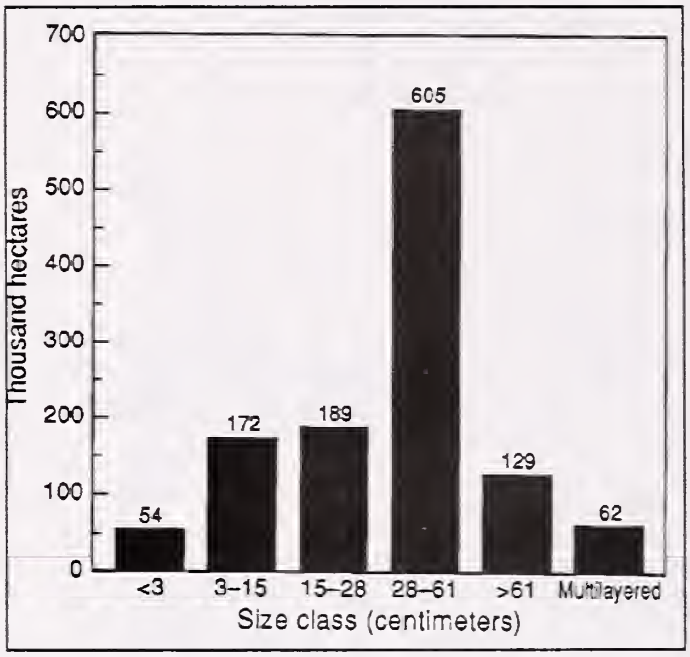

Figure 6—Timberland outside parks and National Forests by WHR size class, north coast, California, 1985.

Table 4--Area of forest land outside parks and National Forests by WHR tree vegetation type, size and canopy closure class, north coast, California, January 1, 1985[a] [b]

Size and canopy closure classes	Redwood	Douglas-fir	Klamath mixed conifer	Ponderosa pine	Closed-cone pine-cypress	Montane hardwood-conifer	Montane hardwood	Valley-foothill riparian	Valley-foothill hardwoods: Coastal oak woodland	Valley-foothill hardwoods: Blue oak woodland	Valley-foothill hardwoods: Valley oak woodland	Valley-foothill hardwoods: Total	All tree types
							Thousand hectares						
<3 centimeters	29 ± 11	14 ± 7	--	--	--	3 ± 3	8 ± 5	--	--	--	--	--	54 ± 14
3-15 centimeters:													
0-24% cover	11 ± 5	14 ± 7	--	--	--	8 ± 5	14 ± 6	--	--	--	--	--	47 ± 12
25-39% cover	8 ± 5	13 ± 6	--	--	--	3 ± 3	3 ± 3	--	--	--	--	--	27 ± 9
40-59% cover	5 ± 4	32 ± 10	--	--	--	3 ± 3	--	--	--	--	--	--	40 ± 11
60-100% cover	12 ± 6	30 ± 9	--	--	--	--	15 ± 7	--	--	--	--	--	57 ± 13
Total	36 ± 10	88 ± 16	--	--	--	15 ± 7	32 ± 10	--	--	--	--	--	172 ± 21
15-28 centimeters:													
0-24% cover	12 ± 6	6 ± 4	--	4 ± 3	--	--	8 ± 6	--	--	--	17 ± 17	17 ± 17	46 ± 12
25-39% cover	3 ± 3	--	--	4 ± 4	--	7 ± 5	21 ± 8	3 ± 3	17 ± 8	--	--	17 ± 17	55 ± 13
40-59% cover	11 ± 6	9 ± 5	--	--	--	6 ± 4	68 ± 14	--	3 ± 3	--	--	3 ± 3	97 ± 16
60-100% cover	26 ± 9	15 ± 7	--	--	--	3 ± 3	85 ± 16	--	34 ± 23	--	--	34 ± 23	162 ± 20
Total	52 ± 13	29 ± 10	--	8 ± 6	--	16 ± 7	180 ± 20	3 ± 3	54 ± 13	--	17 ± 17	70 ± 13	359 ± 24
28-61 centimeters:													
0-24% cover	38 ± 11	15 ± 6	--	--	3 ± 3	13 ± 6	12 ± 6	--	--	4 ± 3	17 ± 17	21 ± 8	101 ± 16
25-39% cover	35 ± 11	25 ± 9	3 ± 3	--	--	9 ± 5	26 ± 9	--	--	--	--	--	98 ± 17
40-59% cover	77 ± 16	15 ± 7	--	--	--	3 ± 2	33 ± 11	--	--	--	--	--	128 ± 20
60-100% cover	189 ± 23	42 ± 11	--	3 ± 3	--	3 ± 3	67 ± 13	--	3 ± 3	--	3 ± 3	6 ± 4	311 ± 26
Total	340 ± 28	97 ± 17	3 ± 3	3 ± 3	3 ± 3	28 ± 9	138 ± 19	--	3 ± 3	4 ± 3	20 ± 8	27 ± 9	639 ± 32
>61 centimeters:													
0-24% cover	24 ± 10	12 ± 6	--	--	--	--	--	--	--	--	--	--	36 ± 12
25-39% cover	6 ± 4	14 ± 6	--	--	--	--	--	--	--	--	--	--	20 ± 7
40-59% cover	20 ± 8	11 ± 6	--	--	--	--	--	--	--	--	--	--	32 ± 10
60-100% cover	11 ± 5	31 ± 11	--	--	--	--	--	--	--	--	--	--	42 ± 12
Total	61 ± 14	68 ± 14	--	--	--	--	--	--	--	--	--	--	129 ± 19
Multilayered	34 ± 11	29 ± 9	--	c	c	--	c	c	c	c	c	c	62 ± 15
All classes	551 ± 30	325 ± 28	3 ± 3	11 ± 6	3 ± 3	62 ± 13	359 ± 27	3 ± 3	57 ± 13	4 ± 3	37 ± 11	97 ± 15	1,414 ± 21

-- = none found.
[a]Totals may be inexact because of rounding.
[b]Confidence intervals are for the 68-percent probability level.
[c]Vegetation type does not occur in this size class.

Table 5--Area of forest land outside parks and National Forests by shrub vegetation type and age and canopy closure classes, north coast, California, January 1, 1985[a] [b]

Age and canopy closure classes	Vegetation type: Chamise-redshank	Vegetation type: Mixed chaparral	Total
	Thousand hectares		
0% decadence	--	--	--
1-25% decadence:			
0-24% cover	--	--	--
25-39% cover	--	--	--
40-59% cover	--	--	--
60-100% cover	50 ± 19	25 ± 17	74 ± 16
Total	50 ± 19	25 ± 17	74 ± 16
>25% decadence:			
0-24% cover	--	--	--
25-39% cover	--	13 ± 13	13 ± 13
40-59% cover	--	--	--
60-100% cover	--	--	--
Total	--	13 ± 13	13 ± 13
All age classes	50 ± 19	37 ± 18	87 ± 11

-- = none found.
[a]Totals may be inexact because of rounding.
[b]Confidence intervals are for the 68-percent probability level.

Evaluating Habitat Suitability for Wildlife Species

Many approaches to habitat assessment using models of wildlife-habitat relationships are possible (Thomas 1982). These models allow estimates of habitat area to be translated into estimates of current or future habitat suitability—and in some cases population numbers—for particular wildlife species. Wildlife species can be selected to focus management attention on resource production, population recovery, maintenance of population viability, or ecosystem diversity. General, level-one models included in the WHR data base indicate the relative suitability of habitats for reproduction, foraging, and hiding and thermal cover for about 600 terrestrial vertebrates native to California (Laudenslayer and Grenfell 1983, Timossi and Dedon 1987). Habitat ratings are defined as follows:

Rating	Description
High	Best quality habitat for the species
Medium	Good habitat for the species, but not among the best
Low	Used by the species, but does not contribute to population maintenance over time
—	Habitat not used by the species

The ratings are based on the best available information about wildlife species, often the professional judgment of wildlife biologists familiar with the species in natural settings. The ratings are assumed to relate to the capability of a habitat to support relatively high, moderate, and low population densities.

To demonstrate one approach to habitat assessment, I linked the habitat classifications of FIA field plots with the WHR models to estimate area of suitable habitat for eight wildlife species along the north coast. The species were selected somewhat arbitrarily to include a mix of herpes, birds, and mammals whose habitat preferences encompass a wide range of vegetation types and successional stages. Most of the eight species are of special interest to resource managers and planners, researchers, or the public. Except where otherwise noted, the species' habitat preferences are summarized below from a USDA Forest Service report;[5] additional information can be found in Verner and Boss (1980), Maser and others (1981), and Brown (1985).

Pacific giant salamanders (*Dicamptodon ensatus*) forage on the forest floor and under ground debris in dense, mature stages of tree habitats. The species requires cold, permanent streams or seeps for breeding. Optimal habitats include riparian deciduous, redwood, and other montane forests. The species is fairly common in optimal habitat.

Optimal habitats for **California quail** (*Callipepla californicus*) include riparian deciduous forest and young, open stands of conifer and hardwood forest. The species requires free water during dry periods. Management activities that develop edges with shrub or open grassland habitats benefit the species. The California quail is designated as a harvest species by the California Department of Fish and Game and also is the California State bird.

[5] Marcot, Bruce G., ed. 1979. California Wildlife-Habitat Relationships Program north coast/Cascades zone. Vol. 1-4. Unpublished report. On file with: USDA Forest Service, Pacific Southwest Region, 630 Sansome Street, San Francisco, CA 94111.

Optimal habitat for **northern spotted owls** (*Strix occidentalis caurina*) include dense, mature, and over-mature stands of redwood, Douglas-fir, and other coniferous forest types. The species is sensitive to habitat fragmentation. The U.S. Department of the Interior, Fish and Wildlife Service, listed the owl as a threatened species in summer 1990.

Pileated woodpeckers (*Dryocopus pileatus*) have been thought to prefer mature stages of Douglas-fir, mixed conifer, and other montane forests as habitat for breeding and feeding. Recent research in northwestern California indicates that the species is numerous in young forests containing mainly hardwoods and few large conifers, and that the birds may be only moderately intolerant to habitat fragmentation (Rosenberg and Raphael 1986). The species excavates cavities and typically selects snags at least 53.3 centimeters d.b.h. The Pacific Southwest Region of the USDA Forest Service has designated the pileated woodpecker a special interest species.

Optimal habitats for **dusky flycatchers** (*Empidonax oberholseri*) include shrubby, open stages of higher elevation forests and mature and decadent stages of chaparral habitats. The species prefers open conifer stands with shrub understories. The dusky flycatcher is a common summer resident and breeder in habitat of medium and high suitability.

Fishers (*Martes pennanti*) prefer riparian deciduous and dense, mature conifer forests. The species is sensitive to human disturbance and habitat fragmentation and is designated a sensitive species by the USDA Forest Service.

Optimal habitats for **mountain lions** (*Felis concolor*) include riparian deciduous forest and open, shrubby stages of most vegetation types. The species avoids human activity and is designated a special interest species by the USDA Forest Service.

Optimal habitats for black-tailed deer (*Odocoileus hemionus*) include riparian deciduous forest and shrubby, open stages of all vegetation types. The deer use meadows with lush vegetation for fawning and feeding during summer. They also require mast, shrub foods, and tree cover on their winter range. The black-tailed deer is designated a harvest species by the California Department of Fish and Game.

Estimated amounts of suitable reproduction and feeding habitat on lands sampled by FIA along the north coast differ greatly for the eight wildlife species (figs. 7 and 8). Comparable summaries for parks, National Forests, and nonforest habitats, if available, might look quite different. About half of the forest area outside parks and National Forests is rated high or medium for reproduction and feeding for the black-tailed deer and mountain lion. Both species use shrubby, open stages of a wide range of vegetation types. About one-third of the forest area rates high or medium for reproduction and feeding by California quail. For spotted owl, 516,000 hectares (34 percent of the forest land) rate as high or medium for reproduction, and 532,000 hectares (35 percent of the forest land) for feeding. Only 14 percent of the forest (216,000 hectares) is of high or medium suitability for reproduction and feeding by pileated woodpecker. For fisher, 25 percent of the area (374,000 hectares) is of high or medium suitability for reproduction and 40 percent (597,000 hectares) for feeding. Pileated woodpecker and fisher both prefer mature forest stages. Because the Pacific giant salamander prefers dense stands, 64 percent of the forest area rates high or medium for its feeding. Aquatic microhabitats required by this species for breeding are neither inventoried by FIA nor accounted for in the level-one models. Only 3 percent of the

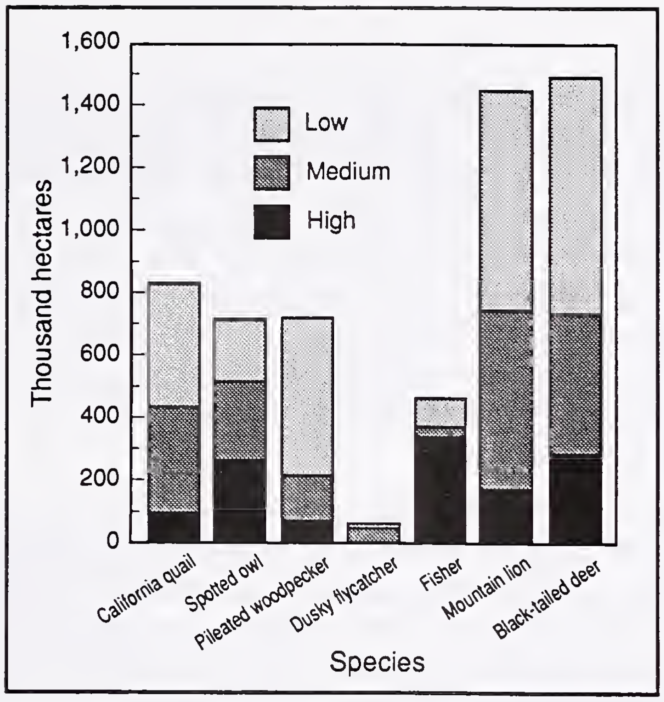

Figure 7—Forest land outside parks and National Forests by suitability for reproduction, north coast, California, 1985.

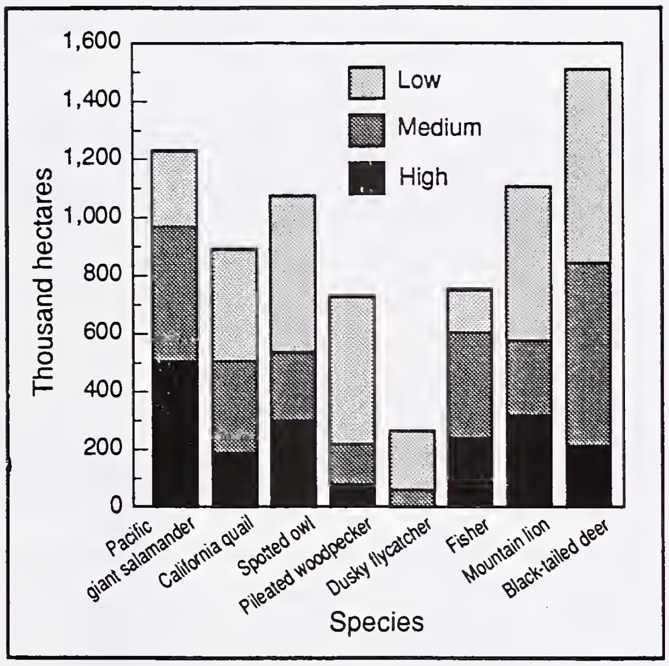

Figure 8—Forest land outside parks and National Forests by suitability for feeding, north coast, California, 1985.

forest habitat is of high or medium suitability for reproduction and feeding by the dusky flycatcher, which prefers higher elevation forest occurring primarily on National Forest lands. The estimates of potentially suitable habitat do not consider special habitat elements such as habitat fragmentation or human activity, which are important considerations in assessing habitat suitability for spotted owl, pileated woodpecker, fisher, and mountain lion. The WHR ratings of habitat suitability used in constructing figs. 7 and 8 are shown in the appendix. Similar summaries could be compiled for other wildlife species by using the habitat area estimates (table 3) and species-habitat models.

Special Habitat Elements in Habitat Evaluations

Applying Level-One Models

The importance to wildlife of special habitat elements needs to be recognized when the level-one models are used to evaluate habitat suitability. Defined here as any element of habitat not explicit in the WHR habitat classification, special habitat elements include diet items or substrates used for feeding, reproduction, or cover. The habitat ratings indicate potential suitability for wildlife; a species will use a habitat if the required special habitat features are present. For species highly dependent on special habitat elements for survival or reproduction, the level-one models alone will be poor at predicting species occurrence for sites lacking the elements. Management for such species requires field verification of the presence of the particular habitat elements and wildlife species.

Although accurate prediction of species occurrence on specific sites is less important in habitat assessments encompassing regions of several hundred thousand hectares, such analyses can be strengthened by considering special habitat elements. The FIA data can be used, for example, to identify the proportion of "suitable" habitat actually supporting needed snag habitat. In forests west of the crest of the Cascade Range, pileated woodpeckers require six hard snags at least 63.5 centimeters d.b.h. and 12.2 meters tall per 40 hectares for nesting if the maximum density of the species is to be maintained (Neitro and others 1985). Hall and Thomas (1979) recommend a management area of 120 hectares with 45 dead trees (15 snags/40 hectares) of appropriate characteristics to accommodate nests and roosts. At the field plot level, FIA sampling procedures for trees at least 63.5 centimeters d.b.h. are not sensitive to differences in densities below 89 trees per 40 hectares. A single tallied snag therefore indicates ample nesting habitat is present. Hard snags at least 63.5 centimeters d.b.h. and 12.2 meters tall were tallied on field plots representing 83,000 hectares of timberland along the north coast: 9 percent of the habitat area rated as high or medium for reproduction, and 6 percent of the area rated as low or not used (table 6). When aggregated across many plots, snag density exceeds six snags per 40 hectares in all suitability ratings, but exceeds 15 snags per 40 hectares only on stands with a high suitability rating (6-percent of the sampled forest land) (fig. 9).

Other Uses of Extensive Inventory Data

Information on special habitat elements collected in extensive inventories can be used in applying species-habitat relationships models other than the WHR models emphasized in this paper. Habitat suitability index models such as those developed as part of the U.S. Fish and Wildlife Service's Habitat Evaluation Procedure (U.S. Fish and Wildlife Service 1980) often require such data. Habitat suitability indices can be tailored to the sample designs and data of extensive inventories, or vice versa (for example, see Sheffield 1981).

Extensive, sample-based inventories offer unique opportunities for ecological studies and resource analyses by providing many permanent plots across a range of ecological provinces and disturbance regimes. Empirical data from these plots can be used to quantify relations between special habitat elements and other stand attributes. Assessments of kinds, amounts, and conditions of habitat elements can be compiled, as in papers by Brooks (1986), Brooks and others (1987), and McComb and others (1986a, 1986b). Remeasurement of permanent plots can provide new information on how various habitat elements change over time as a function of site and disturbance.

Table 6--Area of timberland outside parks and National Forests by habitat suitability for reproduction (see appendix) and by tally of snags suitable for nesting for the pileated woodpecker, north coast, California, January 1, 1985[a] [b]

Habitat suitability	Snags tallied	No snags tallied	Total timberland
		Thousand hectares	
High	9	62	71
Medium	9	118	127
Low	34	471	506
Not used	30	476	505
All habitats	83	1,127	1,210

[a] Sound snags at least 63.5 centimeters d.b.h. and 12.2 meters tall (Neitro and others 1985).
[b] Totals may be inexact because of rounding.

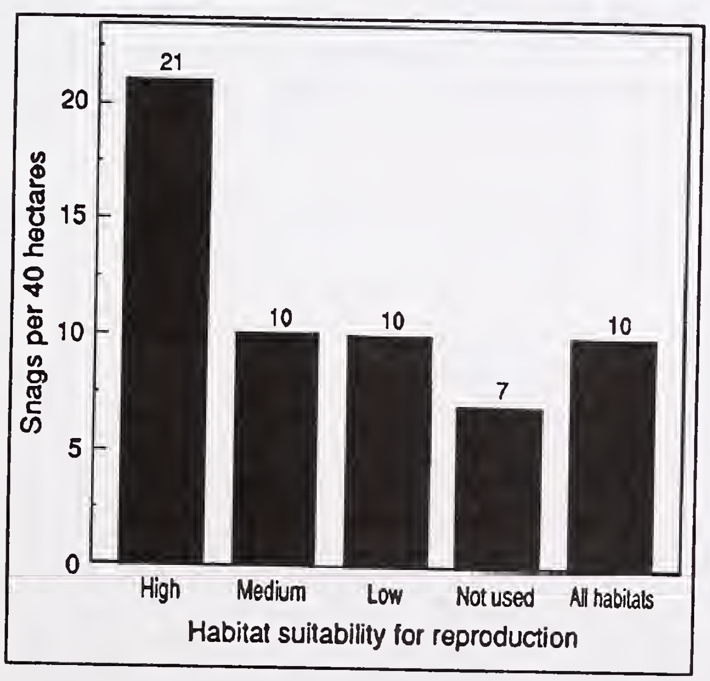

Figure 9—Mean density of snags suitable for reproduction for pileated woodpeckers on forest land outside parks and National Forest, north coast, California, 1985.

The inventory provides descriptive information about the WHR habitats that should prove valuable to others using the WHR habitat classification system and species-habitat relationship models; for example, FIA data for the north coast indicate that large snags (>76 centimeters d.b.h.), which generally are of greatest value to wildlife, are most abundant in dense, pole-sized and larger stands in the redwood type and in large-treed stands of all densities in the Douglas-fir type (table 7). Conifer vegetation types usually support greater densities of these large snags than do the hardwood types. Smaller snags (23-76 centimeters d.b.h.) are most plentiful in the montane hardwood-conifer type. The valley-foothill hardwoods support the lowest snag densities of the tree vegetation types. Also instructive is the relatively high variability in snag populations within the WHR habitats and stages, which indicates the risk in assuming an average snag density for a particular habitat on a particular site. These findings are consistent with those of Raphael and Marcot (1986), who concluded the WHR models are more reliably applied over large geographic areas than at the single-project level. In a forest management context, I recommend direct field observation of snag populations.

Shrub vegetation in tree vegetation types is another important habitat element not considered directly in the WHR habitat classifications. The WHR habitat classifications assume that stands with sparse tree cover support more dense shrub understories than stands with dense tree cover (Verner and Boss 1980), because shrub growth is related to the amount of light that can pass through the tree canopy. Extensive inventory data reveal no consistent relation between tree cover and shrub cover (table 8), thereby indicating the risk in assuming an average shrub cover for a given WHR habitat or stage on specific sites. As with the snag populations, the shrub data reinforce the position that the WHR models are more reliably applied over large geographic areas than at the single-project level. Because shrub cover is influenced by human activities as well as complex interactions of many environmental factors not accounted for in the WHR models, I recommend direct field observation or use of site-specific equations, when available, for predicting shrub cover or biomass.

Table 7--Mean density of snags on forest land outside parks and National Forests, by WHR vegetation type and size and canopy closure classes, north coast, California, January 1, 1985[a]

Vegetation type, size and canopy closure classes	Sample size	Snag d.b.h. 23-37 cm	37-76 cm	>76 cm	Total
		Trees per 40 hectares			
Redwood:					
<15 centimeters--					
0-39% cover[b]	15	394 ± 191	156 ± 86	25 ± 14	575 ± 187
40-100% cover	6	0 ± 0	0 ± 0	0 ± 0	0 ± 0
15-61 centimeters--					
0-39% cover	29	106 ± 53	76 ± 28	36 ± 12	218 ± 66
40-100% cover	88	162 ± 56	71 ± 16	73 ± 15	306 ± 62
>61 centimeters--					
0-39% cover	8	0 ± 0	144 ± 66	35 ± 17	179 ± 74
40-100% cover[c]	20	149 ± 90	205 ± 77	135 ± 40	489 ± 124
All classes	166	158 ± 38	97 ± 16	65 ± 10	320 ± 42
Douglas-fir:					
<15 centimeters--					
0-39% cover[b]	10	293 ± 172	168 ± 132	12 ± 12	473 ± 187
40-100% cover	23	216 ± 89	201 ± 66	45 ± 11	462 ± 103
15-61 centimeters--					
0-39% cover	15	388 ± 210	87 ± 44	7 ± 7	482 ± 240
40-100% cover	27	138 ± 76	107 ± 33	29 ± 12	274 ± 89
>61 centimeters--					
0-39% cover	9	89 ± 89	134 ± 69	52 ± 22	276 ± 92
40-100% cover[c]	24	360 ± 179	144 ± 42	59 ± 15	564 ± 182
All classes	108	249 ± 59	140 ± 24	36 ± 6	426 ± 63
Montane hardwood-conifer:					
<15 centimeters--					
0-39% cover	5	0 ± 0	268 ± 213	0 ± 0	268 ± 213
40-100% cover	1	0 ± NA	0 ± NA	0 ± NA	0 ± NA
15-61 centimeters--					
0-39% cover	9	590 ± 396	134 ± 56	30 ± 15	754 ± 432
40-100% cover	5	419 ± 258	84 ± 84	0 ± 0	503 ± 309
>61 centimeters--					
0-39% cover	0	--	--	--	--
40-100% cover	0	--	--	--	--
All classes	20	370 ± 191	148 ± 61	13 ± 7	532 ± 214

Table 7--(continued)

Vegetation type, size and canopy closure classes	Sample size	Snag d.b.h. 23-37 cm	37-76 cm	>76 cm	Total
		Trees per 40 hectares			
Montane hardwood					
<15 centimeters--[b]					
0-39% cover	9	448 ± 296	304 ± 193	31 ± 22	782 ± 442
40-100% cover	5	0 ± 0	0 ± 0	0 ± 0	0 ± 0
15-61 centimeters--					
0-39% cover	16	97 ± NA	143 ± NA	32 ± NA	272 ± NA
40-100% cover	33	135 ± 65	77 ± 24	25 ± 13	237 ± 77
>61 centimeters--					
0-39% cover	0	--	--	--	--
40-100% cover	0	--	--	--	--
All classes	83	145 ± 54	104 ± 28	26 ± 9	275 ± 70
Valley-foothill hardwoods:[d]					
<15 centimeters--					
0-39% cover	0	--	--	--	--
40-100% cover	0	--	--	--	--
15-61 centimeters--					
0-39% cover	4	0 ± NA	197 ± NA	0 ± NA	197 ± NA
40-100% cover	5	0 ± 0	0 ± 0	0 ± 0	0 ± 0
>61 centimeters--					
0-39% cover	0	--	--	--	--
40-100% cover	0	--	--	--	--
All classes	9	0 ± 0	49 ± 55	0 ± 0	49 ± 55

-- = no field plots taken.
[a]Confidence intervals are for the 68-percent probability level. NA = sample size of 1, or at least one of two combined land classes has sample size of 1.
[b]Includes stands <3 centimeters average d.b.h.
[c]Includes multilayered stands.
[d]Includes coastal oak woodland, blue oak woodland, and valley oak woodland.

Table 8--Mean percentage of cover by shrubs on forest land outside parks and National Forests, by WHR tree vegetation type, size and canopy closure classes, north coast, California, January 1, 1985[a]

Tree vegetation type	Size and canopy closure classes						All classes
	<15 centimeters		15-61 centimeters		>61 centimeters		
	0-39%[b]	40-100%	0-39%	40-100%	0-39%	40-100%[c]	
	Percent shrub cover						
Redwood	32 ± 6	31 ± 8	23 ± 3	21 ± 2	32 ± 6	20 ± 5	23 ± 2
Douglas-fir	20 ± 6	31 ± 6	20 ± 6	17 ± 3	15 ± 6	15 ± 4	20 ± 2
Klamath mixed conifer	--	--	45 ± NA	--	--	--	45 ± NA
Ponderosa pine	--	--	41 ± 27	32 ± NA	--	--	38 ± 16
Closed-cone pine-cypress	--	--	100 ± NA	--	--	d	100 ± NA
Montane hardwood-conifer	26 ± 8	8 ± NA	11 ± 4	8 ± 4	--	--	14 ± 3
Montane hardwood	20 ± 6	45 ± 12	13 ± NA	12 ± 3	--	d	14 ± 2
Valley-foothill riparian	--	--	27 ± NA	--	--	d	27 ± NA
Valley-foothill hardwood[e]	--	--	31 ± NA	23 ± 19	--	d	24 ± 14
All tree vegetation types	25 ± 3	33 ± 4	18 ± 2	16 ± 2	23 ± 5	17 ± 3	18 ± 1

-- = No field plots taken.
[a]Confidence intervals are for the 68-percent probability level. NA = sample size of 1, or at least one of two combined land classes has sample size of 1.
[b]Includes stands <3 centimeters average d.b.h..
[c]Includes multilayered stands.
[d]Vegetation type does not occur in this size class.
[e]Includes coastal oak woodland, blue oak woodland, and valley oak woodland.

Adding a Spatial Dimension to Extensive Habitat Inventories

Wildlife populations respond to the pattern of land forms, vegetation types, and land uses across a landscape as well as to the presence of habitat features on a particular site. Many spatial features of habitat are treated as special habitat elements in the WHR data base and are not accounted for in the wildlife-habitat relationship models. The challenge of including spatial features in habitat evaluations is compounded when data from sample-based inventories are used. Detailed maps of current vegetation based on conventional, large-scale aerial photography are prohibitively expensive to compile for extensive geographic areas. Maps prepared from satellite imagery offer an economical alternative, but they may not provide the desired resolution or accuracy. Even if such in-place information were available, analytical techniques and models for using the data in habitat evaluations for forest management and planning currently are limited. Developing technology in remote sensing and geographic information systems (GIS) offers promise for habitat mapping and analysis.

New procedures for identifying, measuring, and quantifying spatial features of habitat are evolving, many of which can be integrated with extensive inventory designs and data bases. Information on amounts and kinds of edge, stand area, degree of fragmentation, relations between adjacent habitats, and proximity to other land forms and land uses such as streams and roads could be obtained through photo interpretation. Patton (1975), Thomas and others (1979), Rosenberg and Raphael (1986), and Brooks and Scott (1983) offer methods for quantifying edge and other spatial features of habitat. Inventories in Alaska (LaBau and others 1986) and the northeastern United States (Brooks 1986, 1989; and others 1987) have included information on edge habitat in forest assessments.

The methods described above allow the analyst to ascribe spatial attributes to sampled vegetation conditions but still do not permit creation of maps per se. As demonstrated by Oswald (1988), McClure and others (1979), and Sheffield (1981), generalized maps can be created from photo and field plots of extensive inventories. In this approach, Universal Transverse Mercator (UTM) coordinates associated with sample points are used to plot sample locations on a base map of desired scale, with different symbols and colors representing attributes of interest. Figures 4 and 5 show how this kind of map can be used to depict general patterns of habitat over large geographic areas. Users of this kind of map need to remember that areas between plots have not been sampled or observed.

Monitoring and Projecting Changes in Wildlife Habitat

Trends in forest vegetation and wildlife habitat can be monitored through periodic remeasurement of permanent photo and field plots in an extensive inventory. Remeasurement data can be used to monitor changes in habitat conditions at many levels, including structure and species composition of forest vegetation within stands and across forested landscapes and regions. Implications of these trends for wildlife and other forest resources can be evaluated, new problems identified, and forecasts and strategies revised. Given information about projected kinds and amounts of habitats, wildlife-habitat relationship models can be used to evaluate habitat suitability for various points in the future. Projected habitat conditions under alternative scenarios can be objectively evaluated for their ability to satisfy wildlife and timber objectives. This process requires that expected changes in land use and vegetation within the defined geographic area and planning horizon be identified. Future characteristics of forest vegetation, the result of management activities and natural processes of disturbance and forest succession, need to be translated into variables appropriate for evaluating habitat conditions.

Extensive inventory data can be used with the WHR models to project habitat suitability based on a single hypothetical scenario for the future, as demonstrated by Ohmann and Mayer (1987). Several computer models have been developed to aid in habitat monitoring and decision support for integrating timber and wildlife objectives. Choice of a model will depend on the particular objectives (see discussions in Christensen and Davis 1986, Holthausen 1986, Holthausen and Dobbs 1985, Marcot and others 1988, Mayer 1986, Sweeney 1986). Case histories using various computer models to project habitat conditions are presented by Benson and Laudenslayer (1986), Brand and others (1986), Kirkman and others (1986), Shifley and others (1986), and Smith (1986). California's Forest and Rangeland Resources Assessment Program has used the CALPLAN simulation model (Davis and others 1987) to project habitat conditions in the State over a 30-year period (Forest and Rangeland Resources Assessment Program 1988). The development of specific modeling techniques for habitat projection and decision support using extensive inventory data is beyond the scope of this paper.

Interpreting and Using the FIA Habitat Data

Information presented here about wildlife habitats must be interpreted and applied in ways appropriate to the FIA inventory design and data and to the objectives and levels of sophistication of the WHR models. The estimates of habitat area indicate the availability and patterns of occurrence of these vegetation conditions at a broad scale along the north coast. Forest managers, planners, and legislators concerned with wildlife habitats over broad geographic areas can use the information to assess potential impacts of proposed actions that would effect broad-scale alterations of habitat. The sample-based inventory does not provide information on specific locations of stands, and it is not suited to identifying rare or localized habitat elements. The habitat suitability ratings are best interpreted as relative probabilities of occurrence of a species in different habitats and are appropriately used in regional-level predictions of species occurrence and habitat suitability. The ratings are not intended to predict animal occurrence or abundance at specific localities (Nelson and Salwasser 1982, Raphael and Marcot 1986). Many factors not accounted for in the level-one models affect actual animal occurrence and abundance, including presence of special habitat elements, spatial features of habitats, climate, predator-prey relations, interspecific and intraspecific competition, and human activities.

The habitat evaluations given in this paper for the eight wildlife species demonstrate an analytical approach. It is risky to view these selected wildlife species as surrogates or "indicators" for larger groups of species (Block and others 1987, Harris and Kangas 1988, Mannan and others 1984, Patton 1987, Szaro 1986, Verner 1984). Describing habitat resources by suitability for wildlife species may provide additional insight, yet describing plant communities better indicates the total environment. Planners and managers need to remember that, aside from actually monitoring wildlife populations, monitoring vegetation is the most direct way to identify changes affecting wildlife (Patton 1987).

Problems associated with using wildlife species in habitat assessments can be minimized through careful selection of wildlife species for evaluation, careful interpretation of resulting estimates of habitat suitability, and reference to species accounts and distribution maps accompanying the WHR data base. Selected wildlife species should be appropriate to the study objectives and to the source of habitat data, the wildlife-habitat relationships models, the method of habitat evaluation, the geographic location, and the level and scope of analysis. The scale at which wildlife species respond

to their environment is also an important consideration, particularly when sample-based inventory data are used to evaluate wildlife habitat. Home range and territory size should be considered in relation to the overall study objectives, the design of the habitat inventory, and the size of the geographic area being assessed. Sample selection, plot size, and procedures for field data collection used in inventories of forest vegetation often are fixed across all ecological conditions and geographic locations. As in most inventories, these aspects of the FIA inventory design cannot be tailored to specific wildlife species or habitat features of interest without compromising other inventory objectives.

Research and Information Needs

Data presented in this paper apply primarily to lands outside parks and National Forests. Planning and policy decisions require up-to-date information that is consistent across all ownerships in a region. In many cases, valuable data for parks and National Forests exist but are not readily accessible at a central location or in a format or at a scale appropriate for the kind of regional-level analysis included in this paper. A program for regional-scale monitoring of habitat change also is needed.

Communication about forest resources, comparison of research results and habitat surveys, and sharing of data bases would benefit from further standardizing and quantifying of the WHR habitat definitions. Translating data collected from individual trees and other plants into stand variables and classifications has several problems that can be exacerbated by a lack of quantitative guidelines and definitions. Lacking better guidelines, different analysts will classify the same stand differently, depending on the variables used and how they are measured, estimated, or calculated. Most needed are quantitative guidelines for which trees to include in classifying habitat structure and for classifying WHR vegetation type.

Efforts to inventory and evaluate wildlife habitat will benefit from increased knowledge about vegetation response to forest management activities and about natural processes of disturbance and succession for the full range of plant communities, stand conditions, and kinds of disturbances. Dynamics of populations of coarse woody debris should be an important part of this research. Basic data on rates and causes of tree mortality and on snag and fallen tree recruitment, loss, and deterioration are needed. Extensive, sample-based inventories can provide some of this information. Neitro and others (1985) and Raphael and Morrison (1987) offer approaches for coordinating snag management with timber management, but further development is needed. Their approaches could be applied to additional forest types and management regimes and be linked with existing forest inventory data bases and forest projection models.

Habitat evaluations also will improve in quality as models of wildlife-habitat relationships are further improved, updated, and validated. The degree to which these models can be used in forest inventory and monitoring will depend on compatibility between the data required as model input and that collected in the inventories. Increased communication between model builders and users will benefit all parties.

Techniques for measuring, quantifying, and describing spatial features of habitats in regional forest inventories are needed. Cost considerations likely will dictate that approaches to habitat mapping of large geographic areas use remote sensing technology (satellite imagery such as SPOT and LANDSAT). Emerging technology in GIS, including both data display and data analysis, needs to be explored for extensive forest inventories.

Conclusion

The inventory techniques and analytical approach presented here are a preliminary step toward providing tools needed for integrating wildlife considerations into regional forest planning decisions. There is much room to build on the philosophy and procedures I have described.

Terminology

Chaparral—Areas covered with heavily branched dwarf trees or shrubs, mostly less than 3 meters tall, usually evergreen, the crown canopy of which at maturity usually covers more than 50 percent of the ground. In this paper, chaparral is considered "other forest" land.

Forest land—Land that is, or has been, at least 10 percent stocked by trees (10 percent crown cover or 10 percent of normal yield table values), or 50 percent crown cover in chaparral species, and is not now developed for nonforest use. Stands must be 0.4 hectare or larger to qualify.

Forest type—A general descriptor of a forest stand, typically based on the tree species dominating the site.

Habitat—When used in a general sense in this paper, refers to a general vegetative type where a community of organisms exists, or a place that provides the life needs for an organism. In references to the WHR habitat classification system, "habitat" refers specifically to the species composition of the vegetation (that is, WHR vegetation type), and "stage" refers to the structural condition of the vegetation (that is, WHR size, age, and canopy closure classes). See "stage."

Habitat suitability—Qualitative descriptor of how well an area meets the habitat needs of wildlife species for reproduction, foraging, and cover. Relates indirectly to the capability of a habitat to support relatively high, moderate, and low population densities.

Land area—Area reported as land by the Bureau of the Census. Total land area includes dry land and land temporarily or partially covered by water, such as marshes, swamps, and river flood plains, streams, sloughs, and canals less than 200 meters wide; and lakes, reservoirs, and ponds less than 16 hectares.

Land class—A classification of land by major use. The minimum area for classification is 0.4 hectare.

Level-one models—Models in the WHR data base that provide general, qualitative information about the relations between wildlife species and their habitats. The models are based on the best available information, often expert opinion, and are not appropriately used in predicting animal abundance.

Nonforest land—Land that has never supported forests or that formerly was forested and currently is developed for nonforest use. Includes lands used for agricultural crops, Christmas tree farms, improved pasture, residential areas, improved roads, operating railroads and their right-of-way clearings, powerline and pipeline clearings, streams over 9 meters wide, and 0.4- to 16-hectare areas of water classified by the Bureau of the Census as land. If intermingled in forest areas, clearings or other areas must be 0.4 hectare or larger to qualify as nonforest land.

Other forest—Forest land not qualifying as timberland, including woodland and chaparral, as well as rocky and wetland sites.

Quadratic mean diameter—The d.b.h. of a tree of average basal area in a stand.

Reserved land—Land withdrawn from timber utilization by statute, ordinance, or administrative order. Includes National Forest wilderness; National, State, and county parks; and other reservations.

Shrub vegetation type—One of the major WHR habitat subdivisions, including sites where current canopy closure of shrubs is 10 percent or greater and where site potential for tree canopy closure is less than 10 percent.

Stage—The structural condition of the vegetation on a site (that is, WHR size, age, and canopy closure classes), sometimes referred to as "habitat stage." See "habitat."

Timberland—Forest land capable of producing 1.4 cubic meters or more per hectare per year of industrial wood, and that can produce successive crops of trees.

Tree vegetation type—One of the major WHR habitat subdivisions, including sites capable of supporting 10 percent or greater canopy closure of trees.

Vegetation type—In the WHR habitat classification system, refers to the species composition of the vegetation. Also called "habitat" or simply "type."

Woodland—Forest land incapable of producing 1.4 cubic meters or more per hectare per year of industrial wood because of adverse site conditions such as sterile soils, dry climate, poor drainage, high elevation, steepness, or rockiness. Includes steep rocky areas supporting stands of conifers, and areas of oak, pinyon, juniper, and cypress woodlands.

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English Equivalents

1,000 hectares = 2,471 acres

1 hectare = 2.47 acres

0.4047 hectare = 1 acre

1 meter = 3.28 feet

0.3048 meter = 1 foot

1 centimeter = 0.39 inch

2.54 centimeters = 1 inch

1 kilometer = 0.6214 mile

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Appendix

Table 9--Habitat suitability ratings for reproduction (R) and feeding (F) for 8 wildlife species in California[a]

WHR habitat[b]	Pacific giant salamander		California quail		Spotted owl		Pileated woodpecker		Dusky flycatcher		Fisher		Mountain lion		Black-tailed deer	
	R	F	R	F	R	F	R	F	R	F	R	F	R	F	R	F
Redwood:																
1	-	-	-	M	-	-	-	-	-	-	-	-	-	L	L	H
2S	-	L	M	H	-	-	-	-	-	-	-	-	M	H	H	H
2P	-	L	H	H	-	-	-	-	-	L	-	-	H	H	H	H
2M	-	L	H	H	-	L	-	-	-	-	-	-	M	M	M	M
2D	-	M	M	L	-	L	-	-	-	-	-	-	L	L	L	L
3S	-	L	M	H	-	L	-	-	-	-	-	-	M	H	H	H
3P	-	M	H	H	-	L	-	-	-	L	-	L	H	H	H	H
3M	-	M	M	M	M	M	-	-	-	-	-	L	M	M	M	M
3D	-	M	L	L	M	M	-	-	-	-	-	L	L	L	L	L
4S	-	M	M	M	-	L	-	-	-	-	-	L	M	M	M	M
4P	-	H	M	M	-	L	L	L	-	L	-	M	M	L	M	M
4M	-	H	-	-	M	M	L	L	-	-	L	H	L	L	H	M
4D	-	H	-	-	H	H	L	L	-	-	H	M	L	-	L	L
5S	-	M	L	L	-	L	L	L	-	-	-	M	L	L	M	M
5P	-	M	L	L	-	L	L	L	-	L	-	M	L	L	M	M
5M	-	H	-	-	M	M	L	L	-	-	M	H	L	-	M	L
5D	-	H	-	-	H	H	L	L	-	-	H	H	L	-	L	L
6	-	H	-	-	H	H	L	L	-	-	H	H	L	-	L	L
Douglas-fir:																
1	-	-	-	M	-	-	-	-	-	-	-	-	-	L	L	H
2S	-	-	M	H	-	-	-	-	-	-	-	-	M	H	H	H
2P	-	L	H	H	-	-	-	-	-	L	-	-	H	H	H	H
2M	-	L	H	H	-	L	-	-	-	L	-	-	H	M	M	M
2D	-	L	M	L	-	L	-	-	-	-	-	-	M	M	L	L
3S	-	L	M	H	L	L	-	-	-	-	-	-	M	H	H	M
3P	-	M	H	H	L	L	-	-	-	L	-	L	H	H	H	H
3M	-	M	M	M	M	M	-	-	-	L	-	L	H	M	M	M
3D	-	M	L	L	M	M	-	-	-	-	-	L	M	L	L	L
4S	-	L	M	M	L	L	-	-	-	-	-	L	M	H	M	M
4P	-	M	M	M	L	L	L	L	-	L	-	M	H	H	M	M
4M	-	H	-	-	M	M	M	M	-	L	L	H	M	L	H	M
4D	-	H	-	-	M	M	M	M	-	-	H	M	L	-	L	L
5S	-	M	L	L	L	L	L	L	-	-	-	M	M	M	M	M
5P	-	M	L	L	L	L	M	M	-	L	-	M	M	L	M	M
5M	-	H	-	-	L	M	H	H	-	L	M	H	L	L	M	L
5D	-	H	-	-	M	H	H	H	-	-	H	H	L	-	L	L
6	-	H	-	-	H	H	H	H	-	-	H	H	M	L	L	L

Table 9 (continued)

WHR habitat[b]	Pacific giant salamander		California quail		Spotted owl		Pileated woodpecker		Dusky flycatcher		Fisher		Mountain lion		Black-tailed deer	
	R	F	R	F	R	F	R	F	R	F	R	F	R	F	R	F
Mixed conifer:																
1	-	-	-	M	-	L	-	-	-	-	-	-	-	L	L	M
2S	-	-	M	H	-	-	-	-	H	H	-	-	M	H	H	H
2P	-	L	H	H	-	L	-	-	H	H	-	-	H	H	H	H
2M	-	L	H	H	-	L	-	-	M	M	-	-	H	M	M	M
2D	-	L	M	L	-	M	-	-	-	-	-	-	M	M	L	L
3S	-	L	M	H	L	L	-	-	H	H	-	-	M	H	H	M
3P	-	M	H	H	L	L	-	-	H	H	-	L	H	H	H	H
3M	-	M	M	M	M	M	-	-	M	M	-	L	H	M	M	M
3D	-	M	L	L	M	M	-	-	-	-	-	L	M	L	L	L
4S	-	L	L	M	L	M	-	-	H	H	-	L	M	H	M	M
4P	-	M	L	L	L	M	L	L	H	H	-	M	H	H	M	M
4M	-	H	-	-	M	M	M	M	M	M	L	H	M	L	H	M
4D	-	H	-	-	M	M	M	M	-	-	H	M	L	-	L	L
5S	-	M	L	L	L	M	L	L	M	M	-	M	M	M	M	M
5P	-	M	L	L	L	M	M	M	M	M	-	M	M	L	M	M
5M	-	H	-	-	H	H	H	H	L	L	M	H	L	L	M	L
5D	-	H	-	-	H	H	H	H	-	-	H	H	L	-	L	L
6	-	H	-	-	H	H	H	H	-	-	H	H	M	L	L	L
Red fir:																
1	-	-	-	-	-	L	-	-	-	-	-	-	-	L	L	M
2S	-	-	-	-	-	L	-	-	M	M	-	-	M	H	H	H
2P	-	L	-	-	-	L	-	-	M	M	-	-	H	H	H	H
2M	-	L	-	-	-	L	-	-	L	L	-	-	M	M	M	M
2D	-	L	-	-	-	M	-	-	-	-	-	-	M	M	L	L
3S	-	L	-	-	-	L	-	-	M	M	-	-	M	H	M	M
3P	-	M	-	-	-	L	-	-	M	M	-	L	H	H	H	H
3M	-	M	-	-	-	L	-	-	L	L	-	L	M	M	M	M
3D	-	M	-	-	-	M	-	-	-	-	-	L	M	L	L	L
4S	-	L	-	-	L	L	-	-	L	L	-	L	M	M	M	M
4P	-	M	-	-	L	L	L	L	L	L	-	M	M	M	M	M
4M	-	H	-	-	L	L	L	L	-	-	L	H	L	L	M	M
4D	-	H	-	-	L	M	M	M	-	-	H	M	L	-	L	L
5S	-	L	-	-	M	L	L	L	-	-	-	M	M	M	M	M
5P	-	M	-	-	M	L	L	L	-	-	-	M	M	L	M	M
5M	-	H	-	-	M	M	M	M	-	-	M	H	L	L	L	L
5D	-	H	-	-	M	M	M	M	-	-	H	H	L	-	L	L

Table 9 (continued)

WHR habitat[b]	Pacific giant salamander		California quail		Spotted owl		Pileated woodpecker		Dusky flycatcher		Fisher		Mountain lion		Black-tailed deer	
	R	F	R	F	R	F	R	F	R	F	R	F	R	F	R	F
Subalpine conifer:																
1	-	-	-	-	-	-	-	-	-	-	-	-	-	L	L	M
2S	-	-	-	-	-	-	-	-	H	H	-	-	M	H	H	H
2P	-	-	-	-	-	-	-	-	H	H	-	-	H	H	H	H
2M	-	-	-	-	-	-	-	-	M	M	-	-	M	M	M	M
2D	-	-	-	-	-	-	-	-	-	-	-	-	L	L	L	L
3S	-	-	-	-	-	-	-	-	H	H	-	-	M	H	M	M
3P	-	-	-	-	-	-	-	-	H	H	-	L	H	H	H	H
3M	-	-	-	-	-	-	-	-	M	M	-	L	M	M	M	M
3D	-	-	-	-	-	-	-	-	-	-	-	L	L	L	L	L
4S	-	-	-	-	-	-	-	-	H	H	-	L	M	M	M	M
4P	-	-	-	-	-	-	L	L	H	H	-	M	M	L	M	M
4M	-	-	-	-	-	-	L	L	M	M	L	H	L	L	M	M
4D	-	-	-	-	-	-	L	L	-	-	H	M	L	-	L	L
5S	-	-	-	-	-	-	L	L	M	M	-	M	L	L	M	M
5P	-	-	-	-	-	-	L	L	M	M	-	M	L	L	M	M
5M	-	-	-	-	-	-	L	L	L	L	M	H	L	-	L	L
5D	-	-	-	-	-	-	L	L	-	-	H	H	L	-	L	L
Ponderosa pine:																
1	-	-	-	M	-	-	-	-	-	-	-	-	-	L	L	M
2S	-	-	L	M	-	-	-	-	M	M	-	-	M	H	H	H
2P	-	L	M	M	-	-	-	-	M	M	-	-	H	H	H	H
2M	-	L	M	M	-	-	-	-	L	L	-	-	H	M	M	M
2D	-	L	L	L	-	-	-	-	-	-	-	-	M	M	L	L
3S	-	L	L	M	-	-	-	-	M	M	-	-	M	H	M	M
3P	-	L	M	M	-	-	-	-	M	M	-	-	H	H	H	H
3M	-	M	L	L	-	L	-	-	L	L	-	L	H	M	M	M
3D	-	M	L	L	-	L	-	-	-	-	-	L	M	L	L	L
4S	-	L	L	M	-	L	-	-	M	M	-	-	M	H	M	M
4P	-	L	L	L	L	L	L	L	M	M	-	M	H	H	M	M
4M	-	M	L	L	L	L	L	L	L	L	L	H	M	L	M	M
4D	-	M	-	-	M	M	M	M	-	-	H	M	L	-	L	L
5S	-	L	L	L	L	L	L	L	M	M	-	-	M	M	M	M
5P	-	L	L	L	L	L	M	M	M	M	-	M	M	L	M	M
5M	-	M	-	-	H	H	H	H	L	L	M	H	L	L	L	L
5D	-	M	-	-	H	H	H	H	-	-	H	H	L	-	L	L

Table 9 (continued)

WHR habitat[b]	Pacific giant salamander		California quail		Spotted owl		Pileated woodpecker		Dusky flycatcher		Fisher		Mountain lion		Black-tailed deer	
	R	F	R	F	R	F	R	F	R	F	R	F	R	F	R	F
Closed-cone pine-cypress:																
1	-	-	-	M	-	-	-	-	-	-	-	-	-	L	L	M
2S	-	-	L	M	-	-	-	-	-	-	-	-	M	H	H	H
2P	-	-	M	M	-	-	-	-	-	L	-	-	H	H	H	H
2M	-	-	M	M	-	-	-	-	-	L	-	-	M	M	M	M
2D	-	-	M	L	-	-	-	-	-	-	-	-	L	L	L	L
3S	-	L	L	M	-	-	-	-	-	-	-	-	M	H	M	M
3P	-	L	M	M	-	-	-	-	-	L	-	-	H	H	H	H
3M	-	M	M	M	-	-	-	-	-	L	-	-	M	M	M	M
3D	-	M	L	L	-	-	-	-	-	-	-	-	L	L	L	L
4S	-	L	L	M	-	-	-	-	-	-	-	-	M	M	M	M
4P	-	L	L	L	-	-	-	-	-	L	-	-	M	L	M	H
4M	-	M	L	L	-	-	-	-	-	L	-	-	L	L	M	M
4D	-	M	-	-	-	-	-	-	-	-	-	-	L	-	L	L
5S	-	L	L	L	-	-	-	-	-	-	-	-	L	L	M	M
5P	-	L	L	L	-	-	-	-	-	L	-	-	L	L	M	M
5M	-	M	-	-	-	-	-	-	-	L	-	-	L	-	L	L
5D	-	M	-	-	-	-	-	-	-	-	-	-	L	-	L	L
Montane hardwood-conifer:																
1	-	-	-	M	-	M	-	-	-	-	-	-	-	L	L	M
2S	-	-	L	M	-	L	-	-	M	M	-	-	M	H	H	H
2P	-	L	M	M	-	L	-	-	M	M	-	-	H	H	H	H
2M	-	L	M	M	-	-	-	-	L	L	-	-	H	M	M	M
2D	-	L	L	L	-	-	-	-	-	-	-	-	M	M	L	L
3S	-	L	L	M	-	-	-	-	M	M	-	-	M	H	H	M
3P	-	L	M	M	-	-	-	-	M	M	-	L	H	H	H	H
3M	-	M	L	L	L	L	-	-	L	L	-	L	H	M	M	M
3D	-	M	L	L	L	L	-	-	-	-	-	L	M	L	L	L
4S	-	L	L	M	-	-	-	-	M	M	-	L	M	H	M	M
4P	-	L	L	L	-	-	L	L	M	M	-	M	H	H	M	M
4M	-	M	-	-	L	L	L	L	L	L	L	H	M	L	H	M
4D	-	M	-	-	M	M	M	M	-	-	H	M	L	-	L	L
5S	-	L	L	L	-	-	L	L	M	M	-	M	M	M	M	M
5P	-	L	L	L	-	-	L	L	M	M	-	M	M	L	M	M
5M	-	M	-	-	M	M	L	L	L	L	M	H	L	L	M	L
5D	-	M	-	-	H	H	M	M	-	-	H	H	L	-	L	L
6	-	M	-	-	H	H	M	M	-	-	H	H	M	L	L	L

Table 9 (continued)

WHR habitat[b]	Pacific giant salamander R	Pacific giant salamander F	California quail R	California quail F	Spotted owl R	Spotted owl F	Pileated woodpecker R	Pileated woodpecker F	Dusky flycatcher R	Dusky flycatcher F	Fisher R	Fisher F	Mountain lion R	Mountain lion F	Black-tailed deer R	Black-tailed deer F
Montane hardwood:																
1	-	-	-	M	-	-	-	-	-	-	-	-	-	L	L	M
2S	-	-	L	M	-	-	-	-	-	-	-	-	M	H	H	H
2P	-	L	M	M	-	-	-	-	-	-	-	-	H	H	H	H
2M	-	L	M	M	-	-	-	-	-	-	-	-	M	M	M	M
2D	-	L	L	L	-	-	-	-	-	-	-	-	L	L	L	L
3S	-	L	L	M	-	-	-	-	-	-	-	-	M	H	H	M
3P	-	L	M	M	-	-	-	-	-	-	-	-	H	H	H	H
3M	-	M	L	L	-	L	-	-	-	-	-	-	M	M	M	M
3D	-	M	L	L	-	L	-	-	-	-	-	-	L	L	L	L
4S	-	L	L	M	-	-	-	-	-	-	-	-	M	M	M	M
4P	-	L	L	L	-	-	L	L	-	-	-	-	M	L	M	M
4M	-	M	L	L	L	L	L	L	-	-	-	-	L	L	H	M
4D	-	M	-	-	L	L	M	M	-	-	-	-	L	-	L	L
5S	-	L	L	L	-	-	L	L	-	-	-	-	L	L	M	M
5P	-	L	L	L	-	-	L	L	-	-	-	-	L	L	M	M
5M	-	M	-	-	L	L	M	M	-	-	-	-	L	-	L	L
5D	-	M	-	-	M	M	M	M	-	-	-	-	L	-	L	L
Montane riparian:																
1	-	-	-	M	-	-	-	-	-	-	-	-	-	L	L	H
2S	-	-	L	M	-	-	-	-	M	M	-	-	M	H	H	H
2P	-	L	M	M	-	-	-	-	M	M	-	-	H	H	H	H
2M	-	L	M	M	-	-	-	-	L	L	-	-	H	M	M	M
2D	-	L	L	L	-	-	-	-	-	-	-	-	M	M	L	L
3S	-	L	L	M	-	-	-	-	M	M	-	-	M	H	H	M
3P	-	M	M	M	-	-	-	-	M	M	-	L	H	H	H	H
3M	-	M	L	L	L	L	-	-	L	L	-	L	H	M	M	M
3D	-	H	L	L	M	M	-	-	-	-	-	L	M	L	L	L
4S	-	L	L	M	-	-	-	-	-	-	-	L	M	H	M	M
4P	-	M	L	L	L	L	L	L	-	-	-	M	H	H	M	M
4M	-	M	-	-	L	L	L	L	-	-	L	H	M	L	H	M
4D	-	H	-	-	M	M	L	L	-	-	H	M	L	-	L	L
5S	-	L	L	L	M	M	L	L	-	-	-	M	M	M	M	M
5P	-	M	L	L	M	M	L	L	-	-	-	M	M	L	M	M
5M	-	H	-	-	M	M	L	L	-	-	M	H	L	L	M	M
5D	-	H	-	-	M	M	L	L	-	-	H	H	L	-	L	L
6	-	H	-	-	M	M	L	L	-	-	H	H	M	L	L	L

Table 9 (continued)

WHR habitat[b]	Pacific giant salamander		California quail		Spotted owl		Pileated woodpecker		Dusky flycatcher		Fisher		Mountain lion		Black-tailed deer	
	R	F	R	F	R	F	R	F	R	F	R	F	R	F	R	F
Valley-foothill riparian:																
1	-	L	-	M	-	-	-	-	-	-	-	-	-	L	L	M
2S	-	L	M	H	-	-	-	-	-	-	-	-	M	H	H	H
2P	-	M	H	H	-	-	-	-	-	L	-	-	H	H	H	H
2M	-	M	H	H	-	-	-	-	-	L	-	-	H	M	M	M
2D	-	M	H	M	-	-	-	-	-	-	-	-	M	M	L	L
3S	-	M	M	H	-	-	-	-	-	-	-	-	M	H	H	M
3P	-	H	H	H	-	-	-	-	-	L	-	-	H	H	H	H
3M	-	H	H	H	-	-	-	-	-	L	-	-	H	M	M	M
3D	-	H	M	M	-	-	-	-	-	-	-	-	M	L	L	L
4S	-	M	M	H	-	-	-	-	-	-	-	-	M	H	M	M
4P	-	H	M	M	-	-	-	-	-	L	-	-	H	H	M	H
4M	-	H	L	L	-	-	-	-	-	L	-	-	M	L	H	M
4D	-	H	-	-	-	-	-	-	-	-	-	-	L	-	L	L
5S	-	M	M	M	-	-	-	-	-	-	-	-	M	M	M	M
5P	-	H	L	L	-	-	-	-	-	L	-	-	M	L	M	M
5M	-	H	L	L	-	-	-	-	-	L	-	-	L	L	L	L
5D	-	H	-	-	-	-	-	-	-	-	-	-	L	-	L	L
Valley-foothill hardwood:																
1	-	-	-	M	-	-	-	-	-	-	-	-	-	L	-	M
2S	-	-	M	H	-	-	-	-	-	-	-	-	M	H	H	H
2P	-	-	H	H	-	-	-	-	-	L	-	-	H	H	H	H
2M	-	-	H	H	-	-	-	-	-	L	-	-	M	M	M	M
2D	-	-	H	M	-	-	-	-	-	-	-	-	M	M	L	L
3S	-	-	M	H	-	-	-	-	-	-	-	-	M	H	H	M
3P	-	-	H	H	-	-	-	-	-	L	-	-	H	H	H	H
3M	-	-	H	H	-	-	-	-	-	L	-	-	M	M	M	M
3D	-	-	M	M	-	-	-	-	-	-	-	-	M	L	L	L
4S	-	-	M	H	-	-	-	-	-	-	-	-	M	M	M	M
4P	-	-	M	M	-	-	-	-	-	L	-	-	M	M	M	H
4M	-	-	L	L	-	-	-	-	-	L	-	-	L	L	H	M
4D	-	-	-	-	-	-	-	-	-	-	-	-	L	-	L	L
5S	-	-	M	M	-	-	-	-	-	-	-	-	M	M	M	M
5P	-	-	L	L	-	-	-	-	-	L	-	-	M	L	M	M
5M	-	-	L	L	-	-	-	-	-	L	-	-	L	L	M	L
5D	-	-	-	-	-	-	-	-	-	-	-	-	L	-	L	L

Table 9 (continued)

WHR habitat[b]	Pacific giant salamander		California quail		Spotted owl		Pileated woodpecker		Dusky flycatcher		Fisher		Mountain lion		Black-tailed deer	
	R	F	R	F	R	F	R	F	R	F	R	F	R	F	R	F
Chamise-redshank chaparral:																
1	-	-	-	H	-	-	-	-	-	-	-	-	-	M	L	M
2S	-	-	H	H	-	-	-	-	-	-	-	-	L	M	L	H
2P	-	-	H	H	-	-	-	-	-	-	-	-	L	M	L	H
2M	-	-	M	M	-	-	-	-	-	-	-	-	M	H	M	M
2D	-	-	L	L	-	-	-	-	-	-	-	-	M	H	L	M
3S	-	-	H	H	-	-	-	-	-	-	-	-	L	M	M	H
3P	-	-	H	H	-	-	-	-	-	-	-	-	L	M	M	H
3M	-	-	L	L	-	-	-	-	-	-	-	-	M	H	L	H
3D	-	-	-	-	-	-	-	-	-	-	-	-	M	H	L	M
4S	-	-	H	H	-	-	-	-	-	-	-	-	L	M	M	H
4P	-	-	H	H	-	-	-	-	-	-	-	-	L	M	M	H
4M	-	-	L	L	-	-	-	-	-	-	-	-	M	H	L	H
4D	-	-	-	-	-	-	-	-	-	-	-	-	M	H	L	M
Coastal scrub:																
1	-	-	-	H	-	-	-	-	-	-	-	-	-	M	L	M
2S	-	-	H	H	-	-	-	-	-	-	-	-	L	M	L	H
2P	-	-	H	H	-	-	-	-	-	-	-	-	L	M	L	H
2M	-	-	M	M	-	-	-	-	-	-	-	-	M	H	M	M
2D	-	-	L	L	-	-	-	-	-	-	-	-	M	H	L	M
3S	-	-	H	H	-	-	-	-	-	-	-	-	L	M	M	H
3P	-	-	H	H	-	-	-	-	-	-	-	-	L	M	M	H
3M	-	-	L	L	-	-	-	-	-	-	-	-	M	H	L	H
3D	-	-	-	-	-	-	-	-	-	-	-	-	M	H	L	M
4S	-	-	H	H	-	-	-	-	-	-	-	-	L	M	M	H
4P	-	-	H	H	-	-	-	-	-	-	-	-	L	M	M	H
4M	-	-	L	L	-	-	-	-	-	-	-	-	M	H	L	H
4D	-	-	-	-	-	-	-	-	-	-	-	-	M	H	L	M

Table 9 (continued)

WHR habitat[b]	Pacific giant salamander		California quail		Spotted owl		Pileated woodpecker		Dusky flycatcher		Fisher		Mountain lion		Black-tailed deer	
	R	F	R	F	R	F	R	F	R	F	R	F	R	F	R	F
Mixed chaparral:																
1	-	-	-	H	-	-	-	-	-	-	-	-	-	M	L	M
2S	-	-	H	H	-	-	-	-	-	-	-	-	L	M	L	H
2P	-	-	H	H	-	-	-	-	-	-	-	-	L	M	L	H
2M	-	-	M	M	-	-	-	-	-	-	-	-	M	H	M	M
2D	-	-	L	L	-	-	-	-	-	-	-	-	M	H	L	M
3S	-	-	H	H	-	-	-	-	-	-	-	-	L	M	M	H
3P	-	-	H	H	-	-	-	-	-	-	-	-	L	M	M	H
3M	-	-	L	L	-	-	-	-	-	-	-	-	M	H	L	H
3D	-	-	-	-	-	-	-	-	-	-	-	-	M	H	L	M
4S	-	-	H	H	-	-	-	-	-	-	-	-	L	M	M	H
4P	-	-	H	H	-	-	-	-	-	-	-	-	L	M	M	H
4M	-	-	L	L	-	-	-	-	-	-	-	-	M	H	L	H
4D	-	-	-	-	-	-	-	-	-	-	-	-	M	H	L	M
Montane chaparral:																
1	-	-	-	H	-	-	-	-	-	-	-	-	-	M	L	M
2S	-	-	H	H	-	-	-	-	M	M	-	-	L	M	L	H
2P	-	-	H	H	-	-	-	-	M	M	-	-	L	M	L	H
2M	-	-	M	M	-	-	-	-	M	M	-	-	M	H	M	M
2D	-	-	L	L	-	-	-	-	M	M	-	-	M	H	L	M
3S	-	-	H	H	-	-	-	-	M	M	-	-	L	M	M	H
3P	-	-	H	H	-	-	-	-	M	M	-	-	L	M	M	H
3M	-	-	L	L	-	-	-	-	M	M	-	-	M	H	L	H
3D	-	-	-	-	-	-	-	-	M	M	-	-	M	H	L	M
4S	-	-	H	H	-	-	-	-	M	M	-	-	L	M	M	H
4P	-	-	H	H	-	-	-	-	M	M	-	-	L	M	M	H
4M	-	-	L	L	-	-	-	-	M	M	-	-	M	H	L	H
4D	-	-	-	-	-	-	-	-	M	M	-	-	M	H	L	M

[a] H=high suitability; M=medium suitability; L=low suitability; - = not used.
[b] Size classes: 1=<3 centimeters; 2=3-15 centimeters; 3=15-28 centimeters; 4=28-61 centimeters; 5=>61 centimeters; 6=multilayered. Canopy closure classes: S=0-24 percent; P=25-39 percent; M=40-59 percent; D=60-100 percent.

Source: California wildlife-habitat relationships data base--1986. On file with: California Department of Fish and Game, 1416 Ninth Street, Sacramento, CA 95814.

Table 10--Relations between WHR vegetation types and CALVEG series, used in classifying FIA field plots

WHR vegetation type	CALVEG series
Tree types:	
Redwood	Redwood-Douglas-fir Redwood Sitka spruce-grand fir Grand fir Red alder[a]
Douglas-fir	Douglas-fir Douglas-fir-tanoak-madrone Douglas-fir-pine-madrone Red alder[a] Mixed conifer-fir[b]
Klamath mixed conifer	Mixed conifer-fir[b]
Ponderosa pine	Ponderosa pine
Closed-cone pine-cypress	Bishop pine
Montane hardwood-conifer	Black oak[c] Oregon white oak[c] Canyon live oak[c] Tanoak-madrone[c] Madrone-tanoak[c] Interior live oak[d] Madrone-black oak[c]
Montane hardwood	Black oak[c] Oregon white oak[c] Canyon live oak[c] Tanoak-madrone[c] Madrone-tanoak[c] Interior live oak[d] Madrone-black oak[c]
Valley-foothill riparian	Black cottonwood
Valley-foothill hardwoods:	
Coastal oak woodland	Coast live oak Interior live oak[d] California bay-buckeye[e]

Table 10 (continued)

Blue oak woodland/ blue oak-Digger pine	Blue oak-Digger pine Blue oak Interior live oak[d] California bay-buckeye[e]
Valley oak woodland	Valley oak
Shrub types:	
Chamise redshank	Chamise
Mixed chaparral	Whiteleaf manzanita-toyon Whiteleaf manzanita Scrub oak

[a]Classified as montane riparian, Douglas-fir, or redwood based on geographic location, physiographic features, and stand composition.

[b]Classified as Klamath mixed conifer if plot is located in the Klamath Mountains Province (as delineated by Irwin 1966); otherwise classified as white fir or Douglas-fir based on geographic location and stand composition.

[c]Classified as montane hardwood-conifer if 1/3 or more of tree basal area in the stand is conifer; otherwise classified as montane hardwood.

[d]Classified as blue oak woodland/blue oak-Digger pine, coastal oak woodland, montane hardwood, or montane hardwood-conifer based on geographic location and stand composition.

[e]Classified as blue oak woodland/blue oak-Digger pine or coastal oak woodland based on geographic location and stand composition.

Source: Modified from deBecker and Sweet 1988.

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Ohmann, Janet L. 1992. Wildlife habitats of the north coast of California: new techniques for extensive forest inventory. Res. Pap. PNW-RP-440. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 48 p.

A study was done to develop methods for extensive inventory and analysis of wildlife habitats. The objective was to provide information about amounts and conditions of wildlife habitats from extensive, sample-based inventories so that wildlife can be better considered in forest planning and policy decisions at the regional scale. The new analytical approach involves identifying habitats present on field plots, estimating area present in each habitat condition, and linking the habitat classifications with wildlife-habitat relationship models to describe habitat suitability for wildlife species.

Keywords: Wildlife-habitat relationships, multiresource inventory, forest inventory, wildlife habitat assessment, snags, California (north coast).

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